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DR. DONALD C. BARTON

Memorial

Donald Clinton Barton died in the Memorial Hospital in Houston, Texas on July 8, 1939. He had been in the hospital for some weeks and appeared to be recovering from a streptococcic infection when pneumonia developed and proved fatal.

He was born at Stow, Massachusetts on June 29, 1889 and graduated from Harvard in 1911. He obtained his M.A. at Harvard in 1912 and his Ph.D. in 1914 when he was awarded the Sheldon Travelling Fellowship. For the next two years he was instructor in geology at Washington University, St. Louis. After a year with the Empire Gas and Fuel Company he "joined up" in 1917 and served with the A.E.F. in France. In 1919 he returned to civilian life as Division Geologist for Amerada Petroleum Corporation in the Gulf Coast of Texas and Louisiana. He was intensely interested in the geology and physiography of the salt dome province of the Gulf Coast. The study of the origin and mechanics of formation of salt domes and of cap rock was his hobby as well as his vocation.

In 1922 Mr. E. L. DeGolyer of Amerada Petroleum Corporation sent him to Europe to investigate the application of the torsion balance, magnetometer and seismograph to the finding of geologic structure especially in the Gulf Coast. Mintrop was experimenting with his portable seismograph at Hannover, Germany. Ambronn and Mainka at Göttingen were using magnetometers and the Eotvos Torsion Balance had been known and used from time to time in academic work over a period of twenty years. Barton spent some time investigating these methods and in the fall of 1922 two torsion balances were delivered to him in Houston and put in the field by him late that year.

The method of taking the readings and calculating the gradients and curvature had been shown to him in Hungary but there was no guide to interpretation. The interpretation of the results in their re-

lation to structure was a field in which he pioneered and in which he continued to be an authority. He had recognized and was attempting to take out "regional" gravity effects as early as 1926, and he was calculating sections of salt domes and salt dome structure from this date. His earlier studies of soils and their weathering also enabled him to appreciate the effects of near-surface material on geophysical measurements.

Throughout his career Dr. Barton maintained his interest in physiography and gave much time to this study in the Gulf Coast plain. His interest in the subject quickened his recognition of the importance of aerial photography as a tool of the geologist. He was an enthusiastic student of the photographs as soon as they were available and became a recognized authority on their interpretation. As always, he was willing to discuss freely the results of his research and talked on it at meetings of those interested. His paper on "The Art of Reading Aerial Photomosaics" was read at the Short Course on Aerial Photographic Mapping and Geological Exploration at Oklahoma University in February, 1939.

Dr. Barton was chief geologist for Rycade Oil Corporation 1923 to 1926. Oil has since been found through deep drilling on many of the prospects in which the Rycade Oil Corporation was interested during these years. He was consulting geologist and chief of the magnetic and gravimetric section of the Geophysical Research Corporation 1926–1927. From 1927–1934 he was consulting geologist and geophysicist with offices in the Petroleum Building, Houston. During this period he specialized in gravimetric surveys and was employed as a consultant in gravity work done in this and many foreign countries. Since 1934 he had been research and consulting geologist and geophysicist with the Humble Oil and Refining Company, a position for which he was eminently suited and which he thoroughly enjoyed.

Dr. Barton was one of the organizers of the Society of Petroleum Geophysicists, now the Society of Exploration Geophysicists, and served as president in 1931–1932. During his tenure of office the society became affiliated with the American Association of Petroleum Geologists in whose affairs he had for many years been prominent. He was president of the American Association of Petroleum Geologists for the term 1938–1939 and served on important committees, notably the Research Committee, of that organization over the past twenty years.

His wide interest in geology, especially salt dome geology, and in

gravimetric work was attested by the scientific societies of which he was an active member; American Association of Petroleum Geologists; Society of Exploration Geophysicists; Geological Society of America; Society of Economic Geology; Society of Economic Paleontology and Mineralogy; American Institute of Mining and Metallurgical Engineers; Geophysical Union; Deutsche Geophysikalische Gesellschaft; Société Geologique de France; Meteorological Society.

He was a prolific writer and contributed papers to many of these societies. The majority of his papers, however, were published in the Bulletin of the American Association of Petroleum Geologists. His early papers were on the geology of arkose and of disintegration of granite. They were followed by papers on the geology of salt domes; the geology and physiography of the coastal plain area of Texas; the oilfields of Texas and Louisiana; geophysical methods of prospecting; the origin of petroleum. He had been interested for many years in correlating the characteristics of crude oils with the ages of the formations in which they are found and had given much time, over a period of fifteen years, to research on this problem. This research was the subject of his presidential address before the American Association of Petroleum Geologists in March, 1939. His final paper will be a discussion of the Crosbyton magnetic and gravimetric high in West Texas where his early studies have recently been confirmed by the presence of granite in a well drilled in the center of the West Texas Basin.

It was the writer's privilege to do torsion balance work under Barton's direction from 1922 to 1927 and to know intimately those whom he trained in gravimetric and magnetic work during those years. Each of them regarded Doc as one of his best friends as well as his boss. That friendship lasted through the succeeding years and Dr. Barton did his utmost to help them at any time he could whether or not they were still in his organization.

The passing of Dr. Barton at an age when he was in the prime of life and leadership in the field of geology and geophysics leaves a gap which cannot be filled. He will continue to be known for his contribution to, and painstaking research in, geology and geophysics and he will continue to be remembered and respected by those who worked with and under him.

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REFRACTION AND REFLECTION OF SEISMIC WAVES—II DISCUSSION OF THE PHYSICS OF REFRACTION PROSPECTING

C. H. DIX†

ABSTRACT

We observe that there are five principal factors governing the intensity of the refracted wave of "refraction prospecting." It is shown that a clear understanding of this process can lead to decided improvements in the geophysicist's interpretation of refraction data.

INTRODUCTION

The object of this paper is to point out the physical process by which the refracted wave, in refraction prospecting, is generated.[1] It will appear that the actual cases will involve influencing factors quite as important as the discontinuity of elasticity and density at the interface. Thus the intensities given by Jeffreys,[2] Muskat,[3] and Wolf,[4] must be regarded as the roughest approximations to actual conditions.

In Part I,[5] we have raised the question of which path a refraction computer should use in computing a fault: should he consider a ray which follows the interface (including the fault face) closely, or should he draw a least-time path? It is believed that the present discussion furnishes an answer to this question.

The physical description may also be used to clarify the meaning of Muskat's work, which, following Sommerfeld's[6] treatment of radio wave propagation, extracts the various waves as contributions of singularities according to Cauchy's residue theorem. Of course, Muskat does not need to discuss the waves in the lower medium, since the

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[1] My attention has been called to the paper by H. R. Thornburgh in the A.A.P.G. Bull., XIV, pp. 185–200 (1930), 'Wave-Front Diagrams in Seismic Interpretations' which presents, on page 189, a description essentially the same as that given in the present note. Since the present note emphasizes the matter and further includes features not treated in Thornburgh's excellent paper, and since there is a great deal of misunderstanding existing in the literature on the subject, perhaps the publication of the present note will serve a useful purpose.

[2] Proc. Camb. Phil. Soc., *23*. 472 (1926).

[3] Physics, *4*, 14 (1933).

[4] GEOPHYSICS, *1*, 319 (1936).

[5] GEOPHYSICS, IV, No. 2, 1939, pp. 81–101.

[6] Annalen der Physik *28*, p. 665 (1909).

effect of the lower medium on the upper medium is introduced in the interface conditions. Because of its power, Sommerfeld's method is likely to remain the best method of treating such problems for some time to come.

THE PHYSICAL PROCESS

Imagine (Fig. I) a source S sending out a pulse. This pulse occupies successive wave-front positions at successive intervals of time. At the fifth time interval, on our scale, the pulse reaches the "critical" position where the refracted wave-front is normal to the interface at D. Now at further successive time intervals, the wave traveling in the

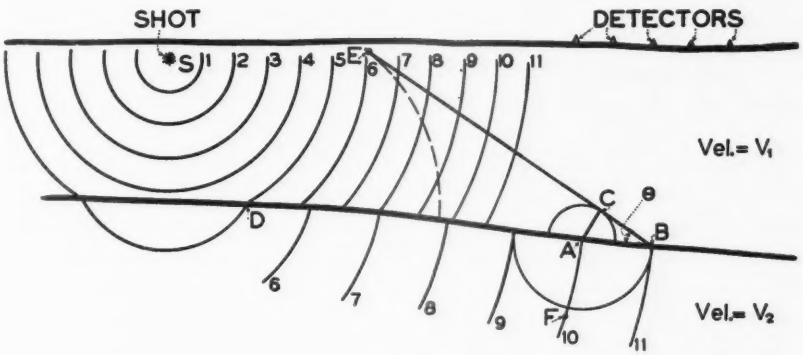

FIG. 1.

lower medium gradually draws away from the pulse in the upper medium. We have therefore the result that to the right of the point D, as we travel with the faster pulse, the lower medium is stressed. The conditions of continuity at the interface that always hold imply[7] that there must also be a stress in the upper medium. Thus the pulse in the lower medium clearly gives rise to a disturbance in the upper medium traveling along the interface with the velocity of the waves in the lower medium. In Fig. 1, ECB is the wave-front generated by the travelling disturbance. From A, the wave travels to B and to C in one interval of time, so that $\overline{AC}/\overline{AB}=v_1/v_2=\sin\theta$.

Now this travelling disturbance moves with a velocity greater than the velocity of waves in the first medium. A similar situation arises in the case of waves generated by a moving boat, or the air waves generated by a fast projectile.

[7] See I, expression (21), p. 88, ref. 5.

This travelling disturbance is the source of the wave used in refraction prospecting. It may be very feeble, or quite strong. The intensity depends, of course, on the intensity of the source. The intensity of the source depends on: (1) the elastic constants and densities of the two media; (2) the distance of the source from the interface; (3) the variation of velocities within the lower medium; (4) the curvature of the interface; and (5) the intensity at the shot-point. The first, second, and fifth effects are taken into account by Muskat's treatment—except that the approximation appears not to have included the second effect. The third and fourth effects are of considerable importance in practice.

Consider especially the effect of velocity variation. When the velocity in the lower medium is constant, the wave at A (Fig. 1) is radiating energy into the upper medium. This radiation can only be accomplished by withdrawing energy from the wave in the lower medium. Thus we find, if we move along the wave-front from F toward A, that the intensity diminishes due to the withdrawal of energy into the upper medium. When the velocity in the lower medium is constant, this withdrawal is replenished only by energy-flow perpendicular to the rays of geometrical seismics. However, when the velocity in the lower medium increases with depth, this withdrawn energy is replaced also by energy flowing along the rays. This latter case is further complicated by reflection back into the lower medium, but the net result is to increase the intensity of the refracted wave. When the velocity decreases in the lower medium, the attenuation due to radiation into the upper medium is increased by the tendency of the energy to be carried away from the interface by the downward curving rays. The effect then depends on the relative curvature of the interface and of the rays. In this way, the third and fourth effects are interrelated. Thus on approaching a structural "high," the intensity of the refracted wave should fall off (aside from possible three dimensional focusing effects) at first, then increase, on leaving the high, to above the value over the plane, and then decrease again to the plane value.

At a fault, we have several effects to take into account. If the shot-point is on the up-thrown side, we may expect the intensity of the first refracted impulse off of the down-side to be a little greater than the intensity of the last refracted impulse off of the up-side (unless the fault plane itself reflects enough energy back to account for the difference), because the wave in the lower layer strikes the interface where its intensity is not so much diminished by radiation into the

upper medium. If the shot-point is on the down-side of the fault, the character of the refracted pulse will change on passing the fault, due to the fact that more emphasis is suddenly placed on the bending of the rays by diffraction; and this introduces a discrimination against the high-frequency components of the pulse, thereby smoothing out any sharp features of the pulse.

We thus arrive at the conclusion that in computing a refraction line across a fault, the part of the profile in which the shot-point is on the high side of the fault is apt to yield better data for the fault-throw computation than the reversed profile data.

Since the whole process is one of diffraction, with the complication of the change of media thrown in, there is some frequency discrimination (see Muskat's equation (36d)) at every stage. It is well to observe however, that this discrimination is accentuated at faults.

In the above description, the effects of shear waves have not been mentioned. The process applies to shear waves as well as to compression waves, and we may expect each travelling source of disturbance to generate both types of waves.

Since the above was worked out, Professor Gutenberg has called my attention to some recent experimental work of O. von Schmidt.[8] Von Schmidt uses a double fluid layer composed of Xylol (sound velocity = 1175 m/s) and NaCl solution (sound-velocity = 1600 m/s). In these media, the "refracted" wave is generated as shown by his spark photographs. The attenuation effect at the interface is quite apparent, as is also the weakening effect of moving the source away from the interface.

[8] Zeitschr. f. Techn. Phys. Nr. 12 (1938) pp. 554–561.

SEISMIC PATHS, ASSUMING A PARABOLIC INCREASE OF VELOCITY WITH DEPTH*

CHARLES E. HOUSTON†

ABSTRACT

This paper discusses the paths of seismic waves, assuming that the velocity increases parabolically with depth. A graph of the reflection time-distance curves, in dimensionless coordinates, is included.

It can be shown that the path of a wave in an elastic medium wherein the velocity is a function of the depth only, $v=v(y)$, can be expressed in the parametric form:

$$x = \int_0^y \frac{pv(y)}{[1 - p^2v^2(y)]^{1/2}}\, dy \tag{1}$$

$$t = \int_0^y \frac{dy}{v(y)[1 - p^2v^2(y)]^{1/2}} \tag{2}$$

where p is a parameter with the two properties,

$$p = \frac{\sin \alpha}{v} = \frac{\sin \alpha_0}{v_0} \tag{3}$$

and

$$p = \frac{dt}{dx}.^1$$

In the above equations

α_0 is the angle of emergence of the wave,

v_0 is the wave velocity at the surface,

α is the angle between the positive y-direction and the wave path away from the surface,

v is the velocity at the depth y,

x is the horizontal distance at which the wave reaches a depth y, and

t is the time required for the wave to travel from the surface to the point x,y.

* Published by permission of the Board of Directors, Humble Oil & Refining Company.

† Geophysics Department, Humble Oil & Refining Company.

[1] On Seismic Computations, With Applications, M. M. Slotnick, GEOPHYSICS, Vol. 1, No. 1, January 1936.

Various forms of the function $v(y)$ have been suggested. The results obtained in such cases provide a means of judging the significance of a given refraction or reflection time-distance curve. The linear case, $v=v_0+ah$, and the exponential case, $v=v_0$ exp ah, have been discussed in detail.[2] The method of expressing the depth as a power series in the velocity has been given by Muskat, with special reference to the following cases:

$$\text{(a)} \qquad y = (v - v_0)(a_0 + a_1 v),$$

the quadratic variation of depth with velocity;

$$\text{(b)} \qquad y = a \log (v_1 + v)(v_1 - v_0)/(v_1 - v)(v_1 + v_0),$$

$$\phi(v) = 2av_1/(v_1^2 - v^2),$$

which permits the velocity to grow asymptotically to a limiting value v_1, and,

(c) an example similar to (b) but one in which the approach is hyperbolic rather than exponential,

$$y = a(v - v_0)/(v_1 - v),$$

$$\phi(v) = a(v_1 - v_0)/(v_1 - v)^2.$$[3]

A linear variation of velocity with *time* has been mentioned in a recent paper by Mott-Smith.[4] The assumption that $v=v_0+at$, however, leads to the parabolic velocity depth function, $v=v_0\sqrt{1+ky}$, which is of the form (a) mentioned above. As Muskat pointed out, because of the transcendental dependence of x and t on the parameter, one cannot obtain $x(t)$ explicitly. The example is of interest however in that the equation of the wave paths can be obtained (in parametric form), the time-distance curve of the direct wave can be computed, and the corresponding reflection time-distance curves can be gotten by graphical methods.

Let us assume,

$$v = v_0\sqrt{1 + kh}. \tag{4}$$

[2] M. M. Slotnick, *loc. cit.*

[3] A Note on the Propagation of Seismic Waves, Morris Muskat, GEOPHYSICS, Vol. 2, No. 4, October 1937.

[4] On Seismic Paths and Velocity-Time Relations, M. Mott-Smith, GEOPHYSICS, Vol. 4, No. 1, January 1939.

With this hypothesis, equations (1) and (2) become:

$$x = \int_0^y \frac{pv_0(1 + ky)^{1/2}}{\{1 - p^2[v_0(1 + ky)^{1/2}]^2\}^{1/2}}\, dy \tag{5}$$

$$t = \int_0^y \frac{dy}{v_0(1 + ky)^{1/2}\{1 - p^2[v_0(1 + ky)^{1/2}]^2\}^{1/2}} \tag{6}$$

$$x = \frac{1}{k(pv_0)^2}\left[(\sin^{-1} pv - \sin^{-1} pv_0) + pv_0(1 - p^2v_0^2)^{1/2} - pv(1 - p^2v^2)^{1/2}\right] \tag{7}$$

$$t = \frac{2}{kpv_0^2}\left[\sin^{-1} pv - \sin^{-1} pv_0\right]. \tag{8}$$

By the use of equation (3), x and t may be written,

$$x = \frac{1}{k \sin^2 \theta_0}\left[(\theta - \theta_0) + \sin \theta_0 \cos \theta_0 - \sin \theta \cos \theta\right], \tag{9}$$

$$t = \frac{2}{kv_0 \sin \theta_0}(\theta - \theta_0). \tag{10}$$

Furthermore, by equations (3) and (4),

$$y = \frac{1}{k \sin^2 \theta_0}(\sin^2 \theta - \sin^2 \theta_0). \tag{11}$$

The equations of the wave path is given in parametric form by equations (9) and (11). By making the following substitutions,

$$\sigma = kx, \qquad \lambda = ky, \qquad \tau = v_0kt,$$

equations (9), (11) and (10) respectively take the form,

$$\sigma + a = R(2\theta - \sin 2\theta) \tag{12}$$

$$\lambda + 1 = R(1 - \cos 2\theta) \tag{13}$$

$$\tau = \frac{2}{\sin \theta_0}(\theta - \theta_0) \tag{14}$$

where,

$$R = \frac{1}{2 \sin^2 \theta_0}$$

$$a = R(2\theta_0 - \sin 2\theta_0).$$

Equations (12) and (13) will be recognized as the parametric equations of a cycloid generated by a circle of radius R rolling along the line $\lambda = -1$, and starting at $\sigma = -a$. The circle rolls with constant velocity,

$$\frac{d\theta}{dt} = \frac{\sin\theta_0}{2}.$$

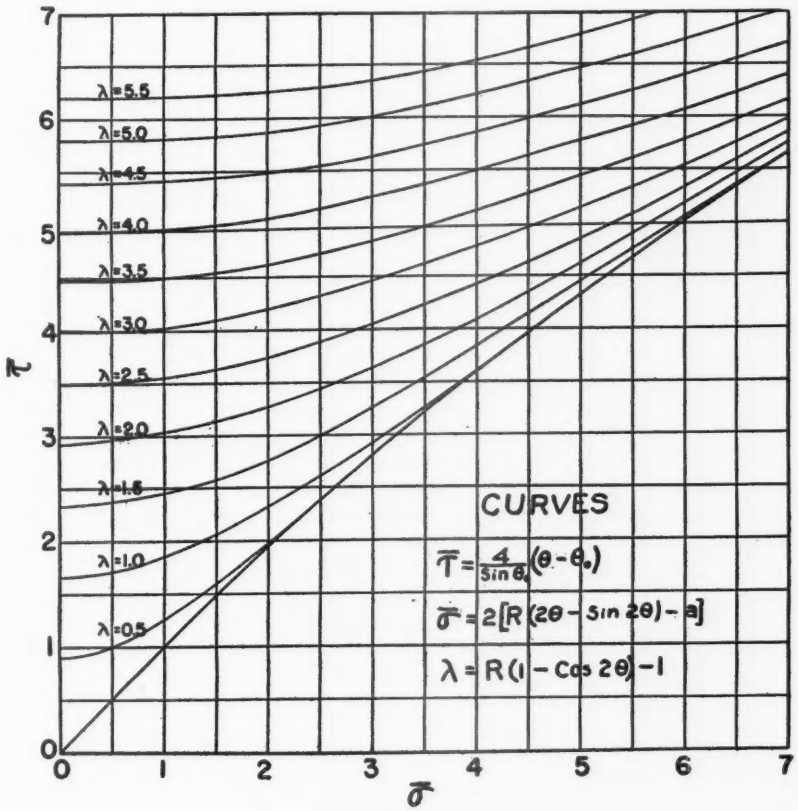

FIG. 1.

If the wave is reflected from a horizontal surface at a depth λ, where $\theta < \pi/2$, it will emerge at a distance $\bar{\sigma} = 2\sigma$ and at a time $\bar{\tau} = 2\tau$. The equations of the reflection time-distance curves are then,

$$\bar{\tau} = \frac{4}{\sin\theta_0}(\theta - \theta_0) \tag{15}$$

$$\bar{\sigma} = 2[R(2\theta - \sin 2\theta) - a] \tag{16}$$

$$\lambda = R(1 - \cos 2\theta) - 1. \tag{17}$$

These curves, corresponding to various values of λ are shown in Fig. 1. For a given value of θ_0, if the wave is not reflected, it will reach the maximum depth when $\theta = \pi/2$, hence it will emerge at the distance $\bar{\sigma}$, at the time $\bar{\tau}$ given by,

$$\bar{\tau} = \frac{2}{\sin \theta_0}(\pi - 2\theta_0), \tag{18}$$

$$\bar{\sigma} = 2(\pi R - a), \tag{19}$$

and the depth of penetration is given by,

$$\lambda = 2R - 1. \tag{20}$$

Equations (18) and (19) which give the envelope of the reflection curves are, of course, the parametric equations of the time-distance curve of the direct wave.

AN AREAL PLAN OF MAPPING SUBSURFACE STRUCTURE BY REFRACTION SHOOTING*

L. W. GARDNER†

ABSTRACT

Under suitable geologic conditions, arrival events of refraction wave trajectories following a relatively high speed "marker horizon" may be observed and identified and the associated travel times may be measured on refraction setups having detectors located at suitable distances from shot point locations. On each refraction setup, the sum of the two "delay times" at positions offset from the shot point and detector position may be determined. Depth of the marker horizon and the location of the "offset position" at which this depth applies are dependent on and determinable from "delay time" if the seismic wave speeds in the geologic section overlying the marker horizon are known. By arranging two or more refraction setups angularly disposed so that they have a common location for one offset position of each setup, differential delay times and corresponding differential depths at the free offset positions may be determined. By a geometrical arrangement of three setups in a triangular manner such that each offset position of each line is coincident with one offset position of another line, absolute delay times and depths at the common offset positions may be determined. By coordinating these two types of geometrical arrangements in shooting over an area, the depths and undulations of the marker horizon may be determined.

The methods and plan of refraction shooting herein described may be successfully applied to areas in which typical favorable geologic conditions exist. These conditions are:

1. That geologic beds shall be lying nearly level, although they may be warped and tilted with dips up to say 10°, and there may be occasional axes of folding with appreciably greater dip or faulting.

2. That there must exist in the geologic section at least one suitable "marker horizon" characterized as described below. A consolidated stratum overlain by a comparatively thick unconsolidated section is ordinarily a suitable marker horizon but suitable marker horizons may also be present under other stratigraphic conditions.

The objective of the methods is to map the surface of a suitable marker horizon or if more than one marker horizon is present, the methods may be applied to any or all of them.

It is known that some of the waves generated at a shot-point will follow trajectories of the type shown in Fig. 1b. A typical graph of travel times of waves following these trajectories vs. shot-point to detector distances called a time-distance curve is shown in the Fig. 1a. The solid line segments of this curve represent "first arrival times."

* Presented at the Annual Meeting, Oklahoma City, March 21, 1939.

† Gulf Research & Development Co., Pittsburgh, Pa.

The dashed line segments of the curve represent arrival times later than the first and these times have the same significance as first arrival times. Either the first arrival times or the later ones shown in the graph may be used as described below but because of the comparative ease and certainty of identifying the initial events and of obtaining

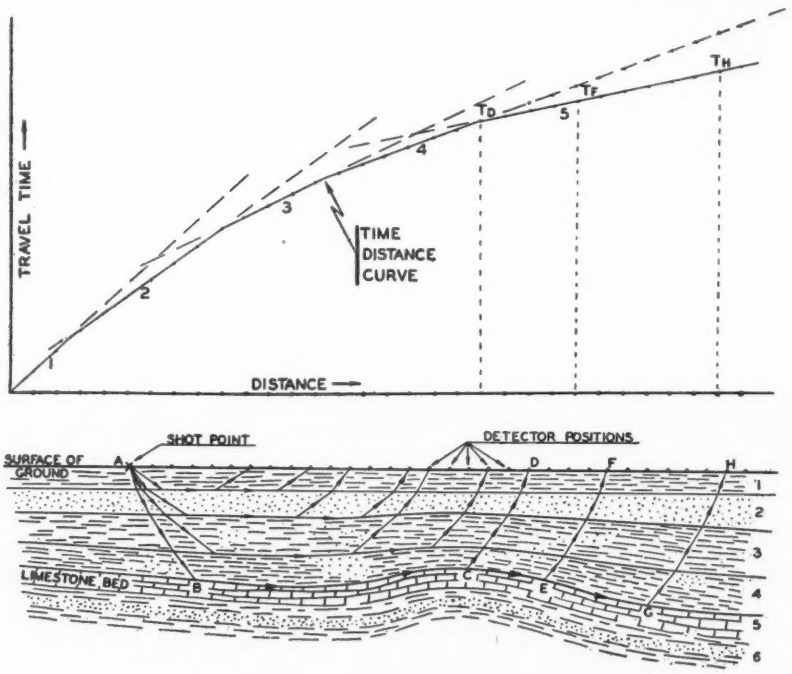

FIG. 1. (a) Graph of Travel time vs. distance; (b) Refraction wave trajectories in typical geologic section.

satisfactory time measurements, first arrival times are most frequently used.

Each segment of the time-distance curve is associated with a particular relatively high speed bed or horizon. The slope of each segment is dependent on the speed and dip of the horizon with which it is associated, the successively smaller slopes of first arrival segments at successively greater shot-detector distances being associated with successively deeper and higher speed horizons. Moreover, the slopes of these segments are the means of determining which horizon is being followed.

If observations on numerous refraction setups made at various places in an area yield time-distance curves which have a "characteristic" well-defined segment, there must exist a corresponding well-defined horizon in the geologic section over the area. Such an horizon is termed a "marker horizon." A "characteristic" well-defined segment has the following properties:

(1) that the associated arrival events on records are clearly identifiable so that travel times may be accurately observed;
(2) that the segment shall be fairly long (3000 feet or more) so that its slope can be definitely established;
(3) that slopes and positions of the segment are comparable on time-distance curves of successive setups.

A suitable "marker horizon" is one present at such a depth that determinations of the undulations of its surface will be geologically significant, and on which observations can be made under practicable operating conditions. Marker horizons conforming with the above requirements are frequently present in areas where petroliferous accumulations are anticipated and exploration by seismograph methods are considered worthwhile. However, upon entering a new area and before proceeding with routine work it is necessary to perform some preliminary sampling refraction operations in order to determine whether or not a suitable marker horizon is present, and to obtain some necessary information for the successful mapping of such a marker. These preliminary operations may consist of shooting one or more groups of setups according to the "Preliminary Shooting Plan" shown in Fig. 2b. This plan yields the following information:

1. The existence of well-defined segments, and marker horizons at appropriate depths.
2. The speeds of marker horizons.
3. The limiting shot to detector distances associated with particular segments or marker horizons.
4. Approximate depths of these markers and "offset distances" associated therewith.

This information of course is incomplete and applies only at the particular locations where the preliminary setups are made but it is sufficient to permit the planning of mapping operations over rather large areas surrounding these setups.

The speed of a given marker horizon is obtained from the slopes of the segments of the time distance curves, and is equal to the reciprocal of the slope of the associated segment if the horizon is level. If the

horizon is dipping, an apparent speed is obtained which is higher or lower than the true speed depending on the direction of dip. By properly averaging the apparent speeds determined from oppositely directed shots, the influence of dip is cancelled, and the true speed is obtained.

It is assumed that over the given area there is lateral uniformity of the speeds in the section overlying any given marker horizon, or that any lateral variations in these speeds are known or determinable by

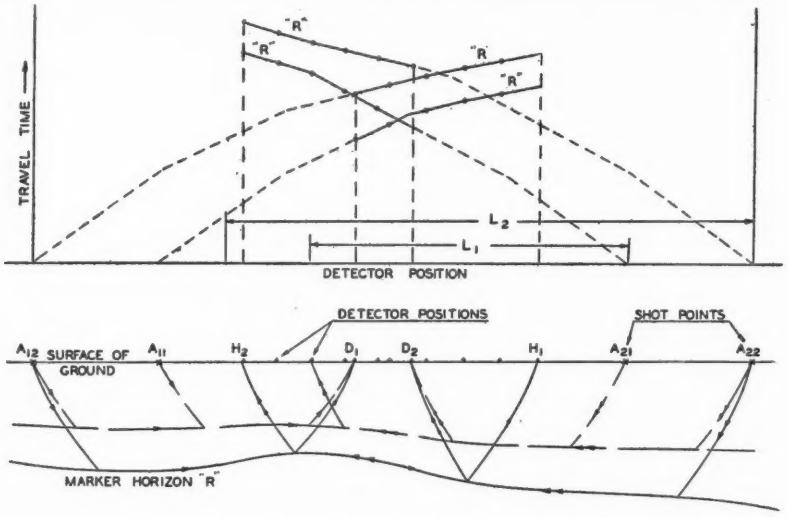

FIG. 2 (a) Time distance curves obtained from preliminary shooting plan; (b) Preliminary shooting plan.

means independent of the method to be described. It is further assumed that the vertical distribution of speeds in the section is known, preferably from well shooting. These assumptions are the same as those ordinarily made in reflection seismograph prospecting. It is still further assumed that the speed of a given marker horizon is constant laterally. The validity of the last assumption is subject to control by determination from the preliminary shooting. Under the above conditions determinations on a given marker horizon may be obtained from observations of only those arrival times which are associated with the given marker horizon. For example, in Fig. 2a, only travel times on segment *R* of the time-distance curve yield determinations on marker horizon *R*, Fig. 2b. Accordingly, in order to obtain data on this marker horizon, it is necessary to place detectors within the limiting distances

L_1 and L_2 from the shotpoint. This requirement must be satisfied in all applications of the methods and plan herein described.

Fig. 3 shows the trajectory $AB'E'F$ of a wave following a given marker horizon R. This trajectory obeys Snell's Law of Refraction; according to which the wave paths AB' and $E'F$ depend on the angular tilts of the beds where they are crossed by these paths. Calculations are simplified by assuming that the waves follow an hypothetical trajectory, different from the actual trajectory and defined as that trajectory which the waves would follow if all the beds were level in the neighborhood of the wave paths AB' and $E'F$. It is represented by $ABEF$. According to Fermat's Principle the travel time along this hypothetical path differs from the travel time along the actual path

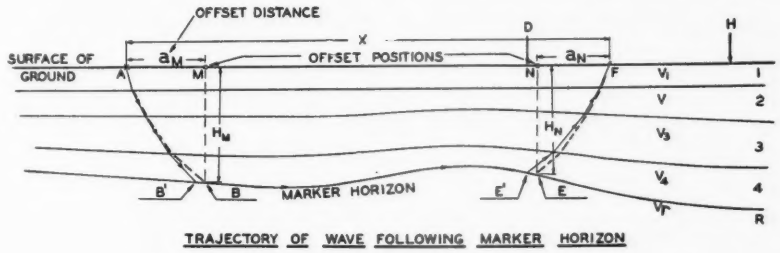

FIG. 3. Trajectory of wave following marker horizon.

by an amount which is dependent only on the second order of variations in path. All calculations may be based on this hypothetical trajectory with only small error which will be zero when beds are level, and increasingly large with increased angle of dip.

Accordingly, the wave travel time

$$T = T_{AB'E'F} = T_{ABEF}$$

and

$$T = t_{AB} + t_{BE} + t_{EF} \tag{1}$$

where t_{AB}, t_{BE}, and t_{EF} are the wave travel times along paths AB, BE, and EF respectively.

Let V_r be the speed of the marker horizon. As stated above, it is assumed to be constant over any given area.

Let

X = shot point to detector distance AF
a_M = AM = Offset Distance
a_N = NF = Offset Distance

then

$$t_{BE} = \frac{BE}{V_r} = \frac{X - a_M - a_N}{V_r}$$

and equation (1) may be written:

$$T = \left(t_{AB} - \frac{a_M}{V_r}\right) + \left(t_{EF} - \frac{a_N}{V_r}\right) + \frac{X}{V_r} \tag{2}$$

Define

$$t_M' = t_{AB} - \frac{a_M}{V_r} = \text{Delay Time}$$

$$t_N' = t_{EF} - \frac{a_N}{V_r} = \text{Delay Time}$$

and

$$b = T - \frac{X}{V_r} = \text{Intercept Time}.$$

Then equation (2) becomes:

$$b = t_M' + t_N'. \tag{3}$$

This is the basic equation of subsequent deductions. Intercept times "b" are determinable from observed data from the relation $b = T - X/V_r$ and are hereinafter regarded as observed quantities. For accurate results in practice, the observed travel time T in this relation must be corrected for shot and detector elevations, and for weathering.

For a given distribution of speeds in the geologic section, t_M' and t_N' are dependent only on the depths H_M and H_N respectively. A relationship between the delay times t', and the depths H may be deduced for any given speed distribution and a graph constructed. Then, if the delay times can be determined from observations, the corresponding depths may be read from the graph. Since the depths H are single valued functions of positions, the delay times t' are single valued functions of positions.

The relationships of depths to delay times and of offset distances to delay times may be obtained from the geometry of the hypothetical wave path, Fig. 4. As stated above, the vertical speed distribution is assumed to be known. Then the speed V in any depth interval ΔH is known.

Let:

ϕ = angle of inclination of hypothetical wave path to the vertical in the depth interval ΔH
Δa = associated increment of offset distance
Δs = associated length of path
$\Delta t'$ = associated delay time

By Snell's Law applied to the hypothetical wave path:

$$\sin \phi = V/V_r.$$

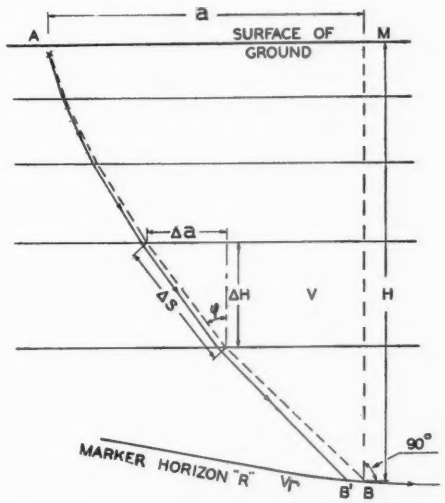

FIG. 4. Portion of wave trajectory and hypothetical wave trajectory.

By Geometry:

$$\Delta H = \Delta s \cos \phi, \text{ and } \Delta a = \Delta s \tan \phi.$$

From the definition of delay time

$$\Delta t' = \Delta s/V - \Delta a/V_r.$$

which reduces to

$$\Delta t' = \frac{\Delta H \cos \phi}{V}$$

in view of the above relations.

The total delay time to any given depth H of the marker horizon

$$t' = \sum \frac{\Delta H \cos \phi}{V}. \tag{4}$$

The total depth of the marker horizon

$$H = \sum \Delta H. \tag{5}$$

Equations (4) and (5) are parametric equations, from which the delay time t' for any given depth H of the marker horizon can be determined.

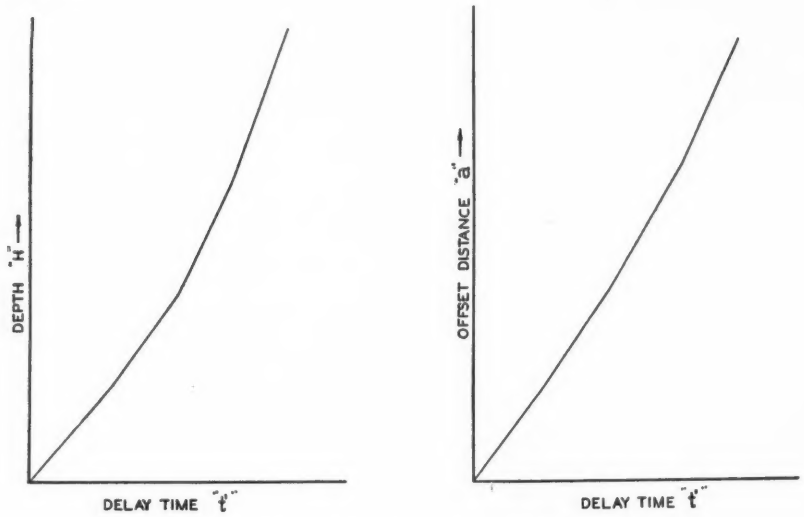

FIG. 5. (a) Depth vs. delay time graph; (b) Offset distance vs. delay time graph.

The total offset distance

$$a = \sum \Delta a$$

or

$$a = \sum \Delta H \tan \phi. \tag{6}$$

Equations (4) and (6) are parametric equations, from which the offset distances for any given delay time can be determined.

Figs. 5a and 5b illustrate the types of depth vs. delay time and offset distance vs. delay time graphs that are frequently obtained. The increase in slopes of these curves with increase in delay time is a consequence of speed of the vertical section increasing with depth.

The independent values of the delay times associated with the two offset positions of a given trajectory can not be uniquely determined from a single setup. Only the sum of the delay times can be determined. However, the average of the delay times may generally be regarded as giving a rough measure of the two delay times.

Methods will now be described for obtaining unique relative and absolute delay time values from geometrically interrelated setups. These methods are applicable when approximate values of offset-distances are known and these can be determined by calculating average delay times from the preliminary and subsequent operational data, and

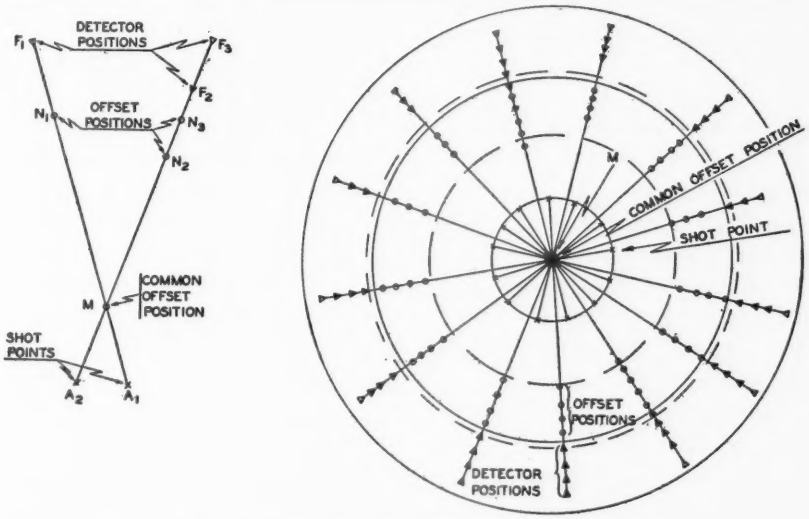

FIG. 6. (a) Element of ring shooting plan; (b) Ring shooting plan.

through use of the offset distance-delay time graph. These values will apply in the localities where the data on which they are based were obtained. Approximate values in other localities may be obtained by interpolations and extrapolations from these values.

RING SHOOTING

Now, if shots are made on two setups A_1F_1 and A_2F_2 shown in Fig. 6a, such that one offset position of one setup is made to coincide approximately in position with one offset position of the second setup, the delay times associated with the common offset-position for the two setups will be practically equal.

Equation (3) applied to the two setups yields:

$$b_1 = t_M' + t_{N_1}'$$
$$b_2 = t_M' + t_{N_2}'$$

whence:

$$b_2 - b_1 = t_{N_2}' - t_{N_1}'. \tag{7}$$

Differences in delay times at the offset positions of the free ends of the setups are thus determinable, being equal to the differences in observed intercept times. The corresponding difference in depths may be obtained by use of the delay-time depth graph.

A detector at F_3 in Fig. 6a receiving waves from shot point A_2 will have a common offset position at M with the detector at F_2. Accordingly,

$$b_2 - b_3 = t_2' - t_3'$$

and the corresponding depth difference may be obtained. A multiplicity of detectors on the line A_2F_2 will yield a multiplicity of relative depth determinations; as well as furnish a means of ascertaining whether or not the chosen marker horizon is being followed. If the chosen marker horizon is not being followed, absurd relative depth determinations usually will be obtained. A number of detectors may be placed on a relatively short line oriented in any direction with respect to A_2F_2, and the offset positions associated with the common shot point will be approximately coincident, so that relative depths associated with the several detectors may be determined.

This system may be extended to a group of such setups having one offset position common, as shown in Fig. 6b. However, the distance requirements on shot-to-detector distances, and the condition of one offset position being common, limit the zone in which detectors may be placed to a ring or annular area and the offset positions at the free ends of the several lines will lie in a smaller ring or annular area. Relative delay times associated with these positions may be determined and expressed in terms of relative depths by use of the delay time-depth graph. Thus, undulations of the marker horizon under the smaller ring or annular area will be determined. A number of such groups of setups may be made, and by arranging them in such a way that one or more control points from adjacent "rings" overlap, it is possible to combine all the data into a map of relative depths over a large area.

A method similar to this has been described by J. H. Jones.[1] How-

[1] "A Seismic Method of Mapping Anticlinal Structures," Proc. World Pet. Congress, Part I, pp. 169–173 (1934).

ever, in his method, shot points of different refraction setups are made common, whereas the condition necessary to the strict application of the theory is that offset positions shall be common. The use of common shot points does approximate this condition, particularly where offset distances are small, and accordingly gives approximate results. However, in mapping marker horizons that are fairly deep, offset distances are comparatively large; and the adjacent offset positions for two angularly disposed setups having a common shot point may be quite widely separated. Accordingly, there is apt to be appreciable

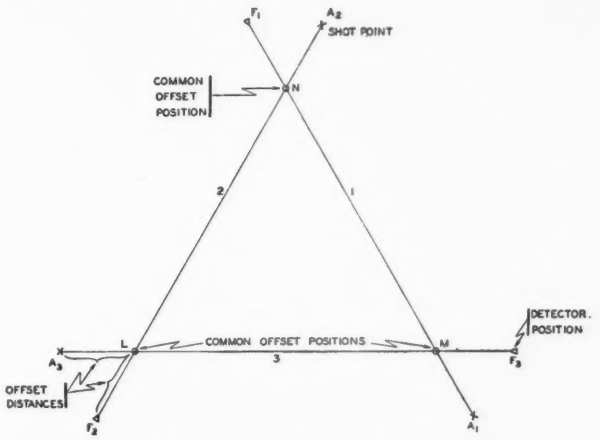

FIG. 7. Triangle shooting plan.

error in the supposition of equality of the delay times associated with these offset positions; with consequent appreciable error in results. This error is practically eliminated by making offset positions approximately common as outlined in the present method.

TRIANGLE SHOOTING

It is possible to shoot three setups in a triangular manner as shown in Fig. 7, such that each offset position of each line is approximately coincident with one offset position of an adjacent line. Applying equation (3) to these three setups gives:

$$b_1 = t_M' + t_N'$$
$$b_2 = t_L' + t_N'$$
$$b_3 = t_L' + t_M'.$$

There are three equations in three unknowns, so the unknowns can be uniquely evaluated.

The solutions are:

$$
\begin{aligned}
t_L' &= 1/2(b_2 + b_3 - b_1) \\
t_M' &= 1/2(b_1 + b_3 - b_2) \\
t_N' &= 1/2(b_1 + b_2 - b_3).
\end{aligned} \tag{8}
$$

By means of the depth-delay time graph, the depths at the corresponding positions, L, M, and N, may be evaluated.

AREAL PLAN OF SHOOTING OVER AN EXTENDED AREA

The methods of both the ring shooting and the triangle shooting may be used in an area to give a number of spaced absolute delay time

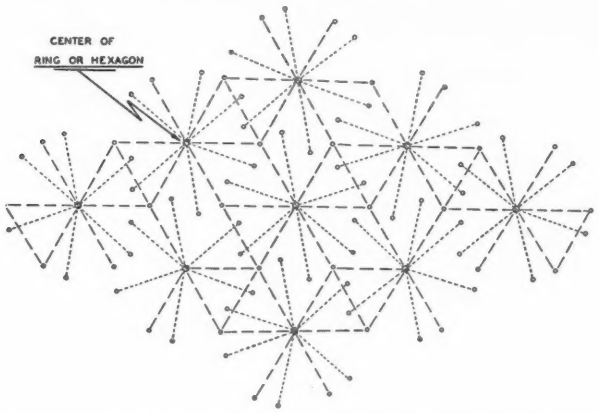

FIG. 8. Areal plan of refraction shooting showing locations of offset positions.

values in an area and intermediate relative delay time values. By coordinating the two types of shooting, the intermediate relative delay time values may be tied to the absolute delay time values so that all the data may be expressed in terms of absolute delay time values, and finally in terms of depths.

A systematic plan for coordinating the data is shown in Fig. 8, which is characterized by triangular and hexagonal geometry. Offset positions are shown in the diagram. It is not necessary that the hexagons be regular. Centers of rings are located in the centers of adjacent hexagons, and shots are made from the center to the six corners of each hexagon. As many additional shots as desired may be made from each center. These shots all conform to the necessary conditions for

forming rings from which relative delay time determinations may be made. In addition as many shots as desired may be made along the sides of the prescribed hexagons, each such shot forming one or two triangles from which absolute delay time determinations may be made. Since the relative delay times are all interrelated with the absolute delay times, they may be expressed in absolute delay times, and converted to depths. Thus, delay time and depth determinations can be made at all offset positions over the area. The use of a multiplicity of detectors for each shot is not necessary to the success of the method, but is desirable from the standpoint of efficiency.

The writer wishes to express his appreciation to Dr. Paul D. Foote and Dr. E. A. Eckhardt of the Gulf Research & Development Company for permission to publlsh this paper.

DIP REFLECTIONS ON TWO FAULTS IN THE GULF COAST*

F. F. CAMPBELL†

ABSTRACT

Two examples of dip reflection work on faulted structures in the Gulf Coast are presented. In one example a large fault is clearly shown by geophysical data alone, and in the other example the assistance of geological data is required to prove the existence of a small fault which the geophysical data alone did not show. The problem of whether misclosure in dip reflection traverses is due to observational errors or faulting is not resolved finally, but suggestions are offered which may lead toward a solution in any particular case.

INTRODUCTION

In a reconnaissance program of dip reflections in the Gulf Coast it is the general practice to lay out shot point and recording stations along straight lines which form a gridwork of traverses. The dip determinations around any particular traverse may be studied from a structural standpoint by proceeding around the traverse, adding the amount of dip in a clockwise direction, and subtracting that in a counter-clockwise direction. The algebraic sum on returning to the starting point is termed, "misclosure." Then the problem is to decide whether the misclosure is due to observational errors and is to be disregarded structurally, or whether the misclosure is to be taken as positive evidence of faulting. Obviously the answer to this problem depends on the quality and quantity of data on the traverse. If the data are poor and scattered, observational errors probably account for the misclosure. But if the data are continuous and of high quality, then faulting is the more probable explanation of a large misclosure. The purpose of this paper is to present two examples of dip reflection work on faulted structures which illustrate the limits of the method.

BACKGROUND OF THE PROBLEM

The problem of misclosure and faulting is not a new one. Dr. E. E. Rosaire and Dr. J. L. Adler, writing on the "Applications and Limitations of Dip Shooting,"[1] examined by statistical analysis 151 closed traverses. They came to the conclusions, first, that misclosures greater than 250′ probably indicate faulting or terracing, and second, that,

* Presented at the Annual Meeting, Oklahoma City, March 21, 1939.

† Geophysical Research Corporation, Tulsa, Okla.

[1] E. E. Rosaire & Joseph L. Adler, Bulletin A.A.P.G. Vol. 18, No. 1, Jan. 1934, pp. 119–132.

"faults having small differential displacement will go undetected in dip reflection work, and may constitute one of its greatest sources of error."

In the field technique described by Dr. Rosaire and Dr. Adler dip determinations were made over short segments and the dip projected across the intervals between segments. The spacing of the dips ranged from 1,400′ to 2,400′ and the length of the measured segments was presumably 500′. The control on the reflection horizons may be measured by expressing the length of segment as a percentage of the spacing of the segments. Hence on the traverses analyzed by Drs. Rosaire and Adler the control ranged from 500′/1,400′ or 35% at a maximum, to 500′/2,400′ or 21% at a minimum. Since 1934 the trend in field technique has been to increase the percentage of control on the reflection horizons up to 100%.

Mr. Henry Salvatori in a paper entitled, "Mapping Faults by the Reflection Method,"[2] described a field technique designed to give 100% control and illustrated the advantages of his method by an example in which a fault is indicated by correlation of several beds directly across the fault plane. Of course, evidence of this kind is the best proof of faulting, but in the Gulf Coast, even when a continuous recording technique is employed, 100% control on one reflection horizon may be far from realized. In order to establish the structural relief around a traverse, dip reflections from several horizons must be used and the dips have to be extrapolated where no reflections can be obtained from any horizon. Also from the standpoint of cost, many operators still do not regard shooting for 100% control as feasible, especially in a reconnaissance program. Consequently, in dip reflection work in the Gulf Coast, appreciable misclosures are not uncommon and the problem of explaining them confronts the interpreter.

Two examples of dip reflection work on faulted structures follow. In example *A*, faulting was proved to be the correct explanation of a large misclosure. In example *B*, although no large misclosure was apparent, faulting is proved by using geological and geophysical data together.

PRESENTATION OF DIP REFLECTION DATA

Fig. 1 exhibits the method of presenting dip reflection data. On the left there is a typical dip reflection record. In the center there is a vertical cross-section of the place where the record was obtained. The

[2] Henry Salvatori, GEOPHYSICS, Vol. II, No. 4, Oct. 1937, pp. 342–356.

shot point and recording stations are indicated at the top and the positions of the segments of reflecting horizons corresponding to each reflection are shown below to scale. The positions of the segments and their inclination are determined by geometrical construction on the assumption of a straight line path. The quality is proportional to the shading of the segment, heavy—good, medium—fair, dashed—poor. On the right there is a map which shows the line along which the shot

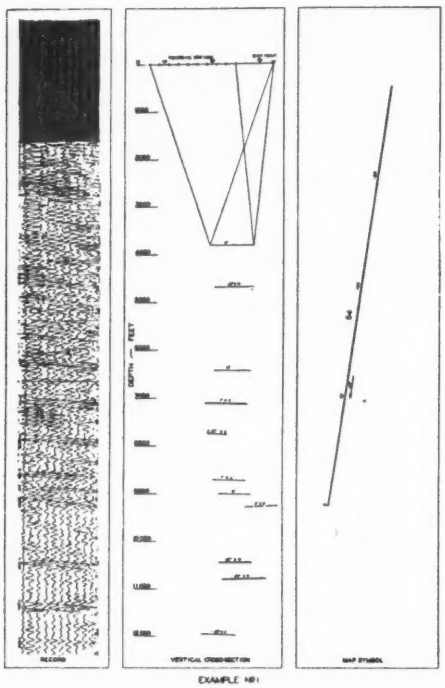

FIG. 1. Method of presentation of dip reflection data. Left—record with reflections identified by letters. Center—vertical cross-section at place where record was obtained. Right—map showing location of line of recording stations and shot points with average dip arrow below.

point and recording stations were arranged, and below this line is the average dip determined by the reflections shown on the record. The amount of dip in degrees is shown by the figure above the arrow. It may be noted that reflections throughout a band of approximately 2,500′ are averaged and called a single horizon on the map. The mid-point of the band corresponds to the depth of the horizon.

EXAMPLE A

The next five figures present part of the data on a prospect which was shot in 1934. The lines of shot points and recording stations were laid out to give more than 100% control because when the work began a small structural anomaly was anticipated. The geophysical data on the whole prospect indicates that the structural feature is a very broad one, and that the faulting is not related to a typical salt dome.

FIG. 2. Example A, map of original traverse with misclosure of 800′ on average dips for 5,000′ horizon.

Fig. 2 is a map of a traverse which showed a misclosure of 800′. The average dips are for the 5,000′ horizon. The amount of dip in a clockwise direction is over 1,200′ and that in a counter-clockwise direction about 400′. The traverse is 65,000′ long. The misclosure would correspond to an error of 12′ per thousand in the same direction all the way around the traverse. This was regarded as very unlikely considering the continuity and quality of the data. Another possibility which

was regarded as even more unlikely was that the misclosure was explained by unobserved dips in the gaps where no data was obtained. Hence the original traverse was cut up as shown in Fig. 3. Inspection of the dips around the traverses in this figure shows that all of them close within 100′ except two, in which all of the dips are in a clockwise direction. There is only sparse data around the traverse bounded by

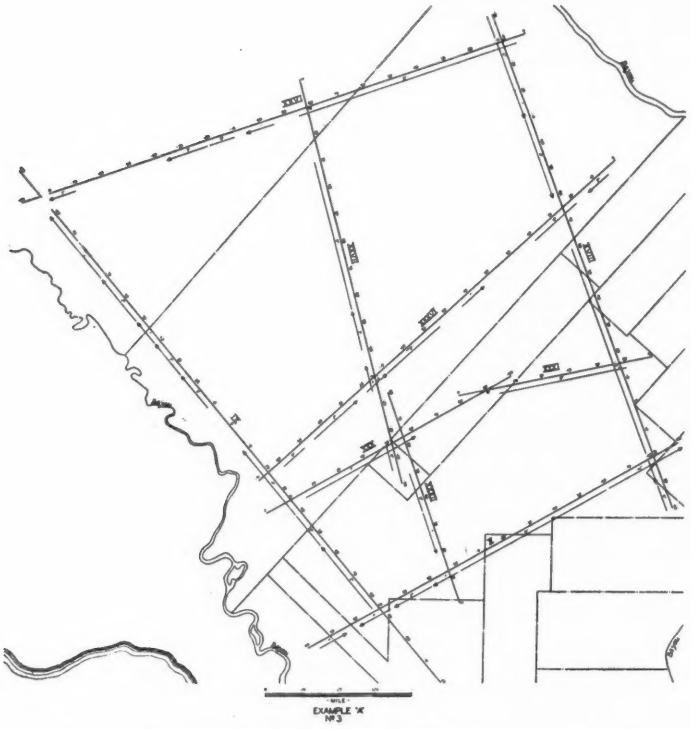

FIG. 3. Example A, map of original traverse and additional lines to isolate misclosure.

lines XVIII, XXXI, XXX, XXVII, and XXXVI, but the data around the traverse bounded by lines XXXII, X, IX, and XXX is practically continuous and it miscloses by some 350′.

The sharp change in the rate of dip on either side of a gap in the data near station 70 on line XVIII had already been noted as suggestive of a fault. A vertical cross-section along line XVIII is presented in Fig. 4. The good reflections marked by the heavily shaded segments on the south end at a depth of 5,000′ are correlated. The ex-

tent of overlapping segments indicates the high percentage of control. Notice the absence of data below station 70 and that the area in which there is no data widens with depth. The dips to the north of this gap are four degrees in magnitude and south of it the dips are less than one degree.

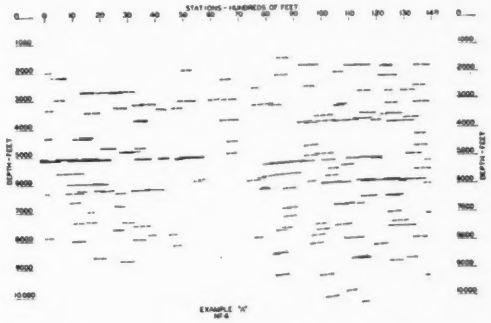

FIG. 4. Example A, vertical cross-section of line XVIII, south end at left.

Fig. 5 is the same as Fig. 4 with the addition of the structural interpretation. The continuous line represents a phantom horizon. It

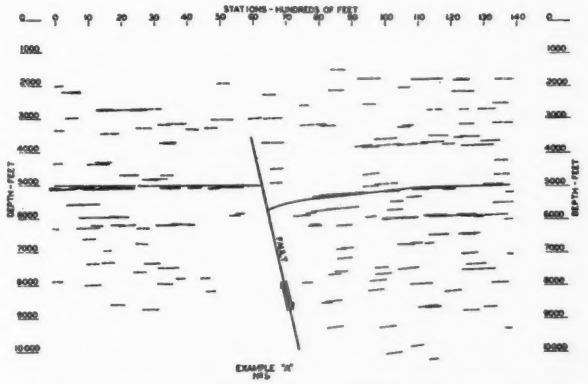

FIG. 5. Example A, vertical cross-section of line XVIII with structural interpretation indicated by continuous line representing 5,000′ phantom horizon.

practically coincides with the correlated data south of the fault, and is projected parallel to adjacent segments north of the fault. The throw of the fault is determined by the misclosure on surrounding traverses, for direct correlation across the fault was considered unwarranted on the data at hand.

Fig. 6 is the same as Fig. 3 with the addition of contours on the 5,000′ phantom horizon. The contour interval is 100′. The trace of the fault coincides with absence of reflection data and the fault plays out opposite station 50 on line IX where a flattening is indicated. The greatest differential displacement occurs in the two traverses previously cited which showed the greatest misclosure.

FIG. 6. Example A, map with contours on 5,000′ phantom horizon. Contour interval 100′.

Although there has been no drilling to substantiate the presence of this fault exactly as shown, it is believed that the geophysical evidence alone is sufficient to demonstrate clearly the presence of a fault of major proportions.

EXAMPLE B

The next four figures present some of the data which were obtained in the spring of 1938 on a small oil field. From previous well

data it might be inferred that accumulation was controlled by faulting, but even so it was anticipated that the geophysical data would show some arching of the sediments.

Fig. 7 is a map of the traverses around and across the field with the average dip data for the 6,500′ horizon. The northwest-southeast lines were shot with 100% control. There is no indication of arching, but there are some short segments of abnormally steep dips. Lines 67

FIG. 7. Example B, map of traverses around small oil field with average dips for 6,500′ horizon.

through 71 form a broken line across the field in a northeast-southwest direction. They do not show any arching either, but there is a significant reversal in the direction of the dips at station 0 on line 68. Inspection of the traverses for misclosure did not reveal any which could not be adjusted within the limits of observational errors.

Fig. 8 is a vertical cross-section along line 55, and shows scattered segments with noticeable southeast dip. The increase of dip with depth may be noted. The only place which comes near to having a complete absence of data is at station 80, and if faulting occurred

there, the deep reflections would have had to penetrate the fault plane.

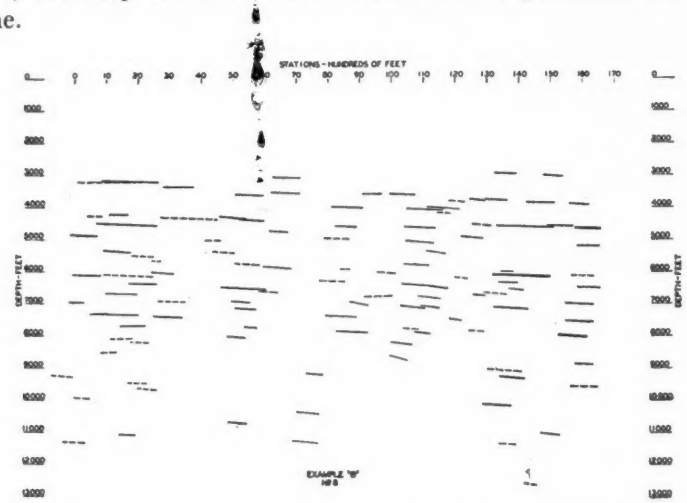

FIG. 8. Example B, vertical cross-section of line 55. Northwest end at left.

Fig. 9 is the same as Fig. 8 with the addition of well data and structural interpretation. The continuous lines mark the base of the

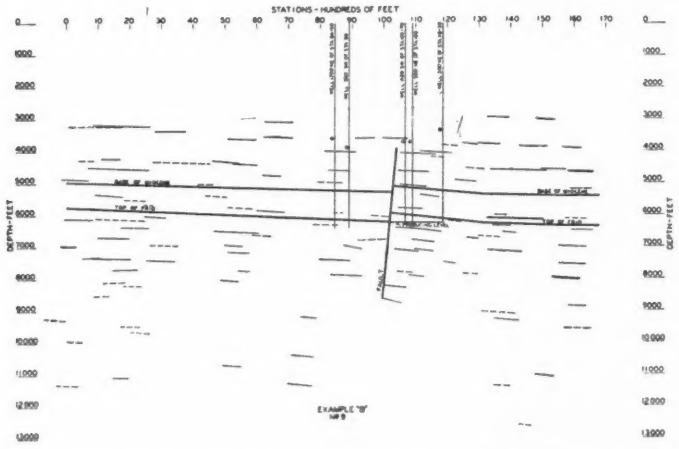

FIG. 9. Example B, vertical cross-section of line 55 with addition of well control and structural interpretation.

marine Miocene sands and the top of the Frio sands. The depths of these horizons are determined at the wells by Schlumberger electrical

logs supported by paleontological evidence. Elsewhere the positions of the horizons are determined by the adjacent dip segments. Thus a fault with 200′ of throw down on the north is shown at station 100.

Fig. 10 is the same as Fig. 7 with the addition of contours on the 6,500′ horizon at 100′ intervals. The contours are tied to the data for the Heterostegina zone of the Oligocene at the wells. Accumulation is controlled by the fault crossing line 55 at station 102 and by a fault

FIG. 10. Example B, map with contours on 6,500′ phantom horizon tied to Heterostegina zone of Oligocene at wells. Contour interval 100′.

crossing line 68 at station 0. The evidence for the second fault is poorer than that for the first one and all of it is not presented in this paper.

In this example dip reflections alone did not indicate faulting although the data does indicate an anomalous area. It is believed that faults of this magnitude would be missed by work of the calibre shown.

CONCLUSION

These two examples of dip reflection work on faulted structures do not define a sharp line on one side of which misclosures can be inter-

preted as faulting, and on the other side of which misclosures must be charged off to observational errors. These examples are limiting cases and they agree with the conclusions of Dr. Adler and Dr. Rosaire.[3] Each operator has to decide for himself where to draw the line depending of course on the field technique used and on the quality and quantity of data obtained. However, in case of a large misclosure on a reconnaissance program shot with less than 100% control, it is recommended that the original traverse be cut up with lines shot for 100% control. Then if the misclosure is concentrated by the additional shooting, faulting is the probable explanation, especially if there is an abrupt change in the magnitude or direction of the dips on either side of a place where no data is obtained.

ACKNOWLEDGMENTS

The writer is indebted to the Geophysical Research Corporation and Amerada Petroleum Corporation for permission to publish this data, and to Mr. Andrew Gilmour, Mr. W. A. Carruth, and Mr. A. E. Smith for assistance in preparing the exhibits.

[3] *Loc. cit.*

SHALLOW RESISTIVITY SURVEY AT SOUTH ELTON, LOUISIANA*

E. E. BLONDEAU†

ABSTRACT

A direct current resistivity survey covering about one and one-half townships adjacent to the South Elton oil field is described. The contour map based on data taken 100′ from a current electrode shows many near surface anomalies while that based on data taken 1000′ from a current electrode is comparatively uniform. Conclusions reached were: First, that Eltran and direct current data show good qualitative agreement; second, that the large observed variations in near surface resistivity can hardly be attributed to mineralization emanating upward over structure; and third, that the number of anomalies found is so great that their direct association with deep structure is highly improbable.

Recently, among petroleum geophysicists, there has been a rather widespread interest in near surface variations of physical properties of the earth. In most previous reports on the subject the data has been limited to small areas adjacent to known anomalies. Hence it is felt that a presentation of the results of a careful and thorough resistivity survey done by the Geophysical Research Corporation at South Elton Field, Louisiana, for the purpose of studying electrical variations may be of general interest.

The resistivity survey was made in a conventional manner, using standard direct current resistivity equipment including non-polarizing potential electrodes, potentiometer, standard cell, ammeter and a current source of lead storage cells. Potential positions were taken inside a 2000′ current spread, usually at 100′ intervals. The fixed potential position was taken at the center of the spread. The whole system was advanced along a line in steps of 1000′ except in detailed regions where 500′ spacing was used. The current was reversed between potential readings at a particular position and the total observed change in potential together with the corresponding change in current (say from minus to plus) furnished the desired data without the necessity for residual or ground potential measurements. A minimum of three pairs of potential readings were taken at each potential position; if potentials were unsteady the number of readings was increased.

Computation of apparent conductivity values was based on the standard formula for a medium of uniform conductivity; namely,

$$k = \frac{1/r_1 - 1/r_2}{2\pi E/I}$$

* Presented at the Annual Meeting, Oklahoma City March 21, 1939.

† Geophysical Research Corporation, Tulsa Okla.

where k is the specific conductivity of the ground, I is the total current through ground, E is the potential at a particular point and r_1 and r_2 are the distances from the point to the two current electrodes.

Values of conductivity displayed in the accompanying figures correspond to three depth zones. The conductivities for the first, or

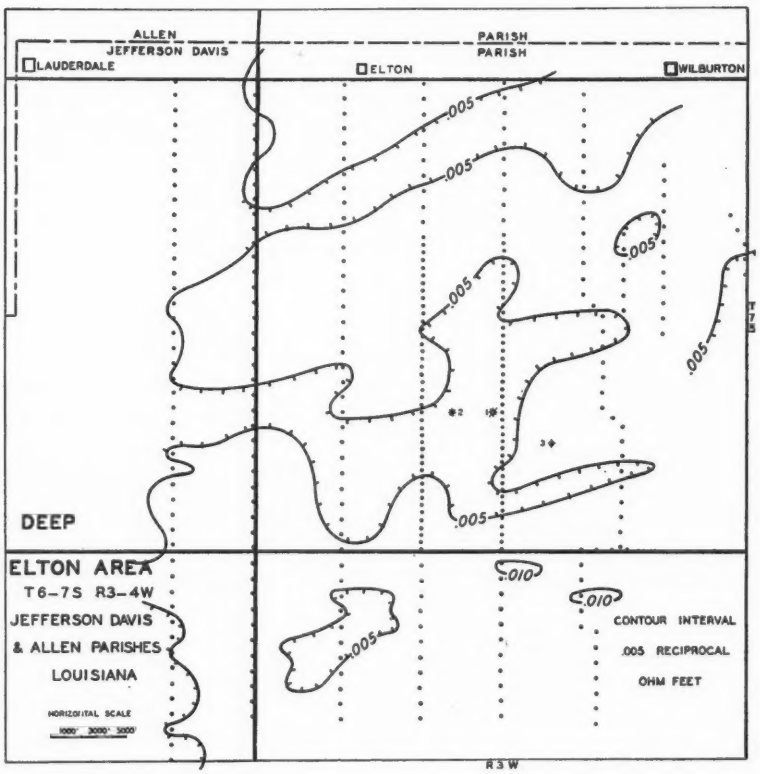

FIG. 1. Apparent conductivity with potential electrodes 900′ and 1100′ from near current electrode.

"shallow" zone, are computed from the potential differences measured between positions 100′ and 300′ from the near current electrode. The second or "medium" zone corresponds to the 400′ and 600′ positions while the last or "deep" zone corresponds to the 900′ and 1100′ positions.

Fig. 1 shows conductivity contours on the "deep" zone. The values show very little variation, hence only one contour appears with any prominence.

Fig. 2 presents data taken closer to the current electrode (400′ to 600′). These data show a little more variation than in the previous figure, and indicate development of closures.

Fig. 3, representing very near surface effects since measurements were taken 100′ from the current electrode, shows many definite highs

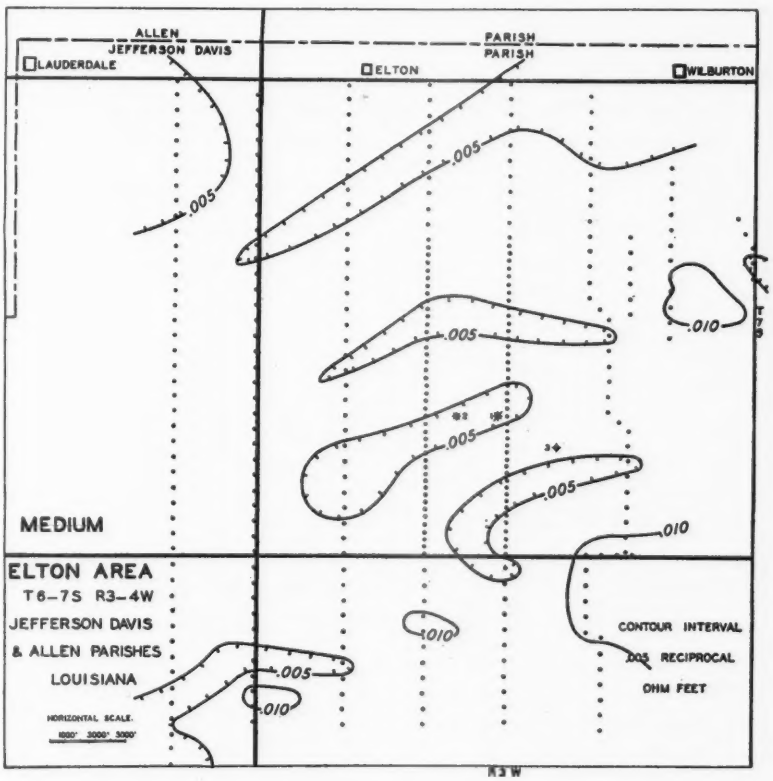

FIG. 2. Apparent conductivity with potential electrodes 400′ and 600′ from near current electrode.

and lows, and also shows variations in conductivity values between nearby points as great as ten to fifteen times.

In this connection a paper[1] by Rosaire is of interest because in it he suggests that variations of surface resistivity may be useful in locating subsurface structures. Rosaire uses Eltran data to support his contention but he has indicated that high resistivity readings correspond

[1] E. E. Rosaire, "Shallow Stratigraphic Variations over Gulf Coast Structure,"—GEOPHYSICS, Vol. III, No. 2, pp. 96–115, March, 1938.

to high Eltran readings.[2] Further experimental evidence of the correspondence between Eltran and resistivity data follows in the present paper.

It is seen in Fig. 3 that to date the results from drilling do agree with Rosaire's hypothesis since both productive wells[3] are on a con-

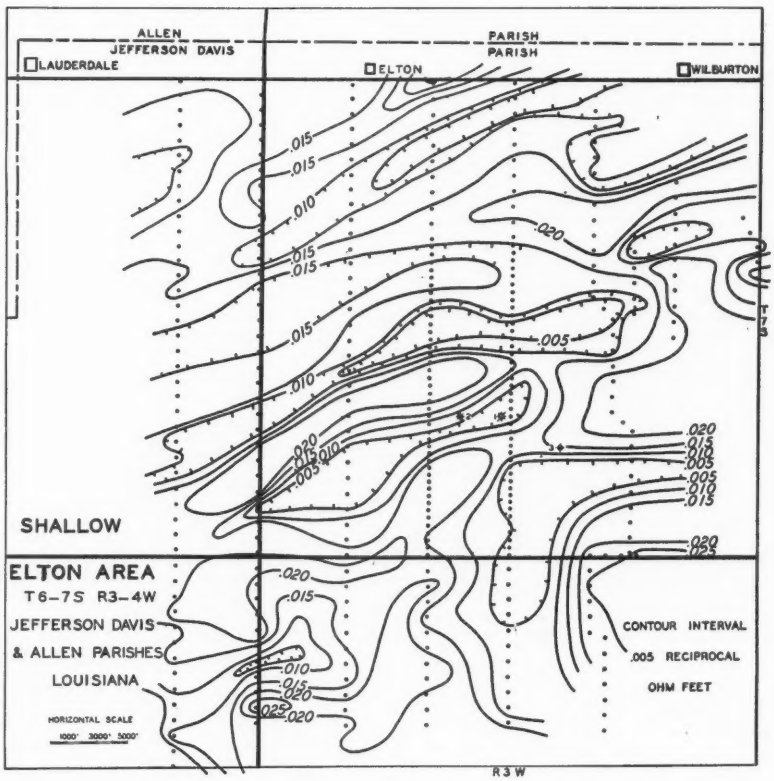

FIG. 3. Apparent conductivity with potential electrodes 100′ and 300′ from near current electrode.

ductivity low (same as resistivity high) and the dry hole is on a conductivity high. However, further inspection of Fig. 3 reveals the fact that five more similar conductivity lows exist in the township mapped. Although it is true that all the areas indicated have not been condemned by the drill, the presence of six distinct oil fields in one town-

[2] Private Communication.

[3] Well #1 blew out, well #2 produces gas and some distillate and well #3 is dry.

ship would be extremely unusual. Furthermore the reflection seismograph data on the basis of which the prospect was discovered and drilled showed only one subsurface structure in the township. The reflection data was of fair quality and was correlatable hence the chance of overlooking five structures in the township was small.

Fig. 4 shows in section data observed along the north-south line passing 2000′ west of well #2. This line is the same as that along which

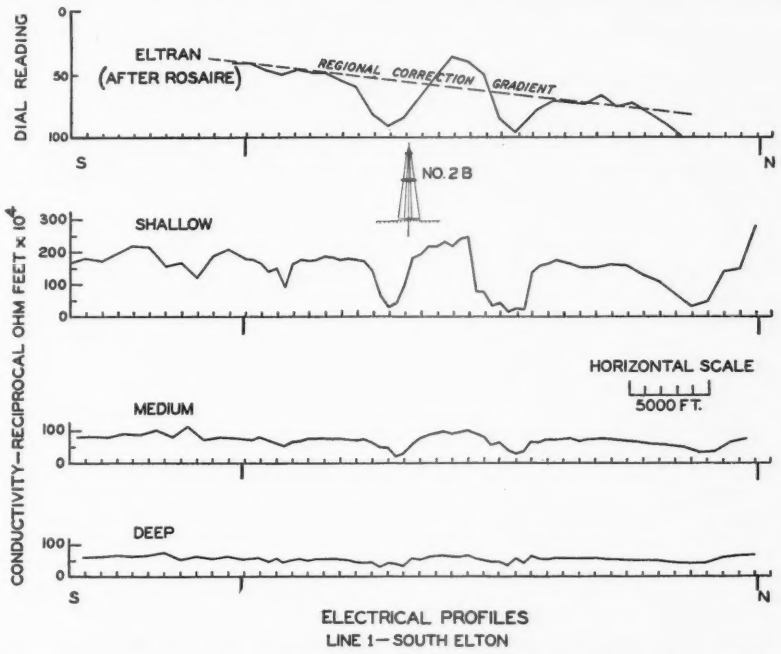

FIG. 4. Apparent conductivity profiles illustrating the effect of increasing depth of exploration. Also showing comparison with an Eltran profile by Rosaire.

Rosaire obtained the Eltran data reported in the paper previously mentioned. An exact reproduction of his data papears in Fig. 6. Hence a comparison can be made between Rosaire's Eltran data and the present direct current results. Attention is called to the fact that in Rosaire's figure the north end of the line appears on the left side of the page while the writer's figures are drawn in the conventional manner with the north end of the line on the right. Also, it should be remembered that in making the comparison a high Eltran or resistivity value should correspond to one of low conductivity. In order to facilitate a direct comparison with the conductivity data Rosaire's Eltran graph has been inverted and turned around as it appears in Fig. 4.

It is obvious that there is an excellent qualitative agreement between the Eltran profile and the profile of "shallow" conductivity data. This is to be expected since conductivity is the major factor controlling the shape of an individual electric transient. Also it seems unlikely that any second order effects such as "ripples" on the individual transient due to other factors, if such existed, could be distinguished from those due to the large horizontal and vertical variations of conductivity.

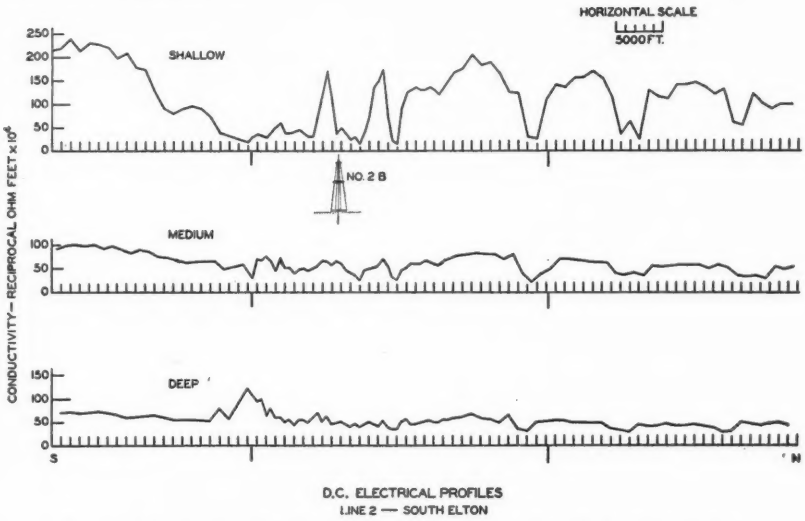

FIG. 5. Apparent conductivity profiles illustrating the effect of increasing depth of exploration. Profile covers 15 miles.

The results of this survey are also of interest in connection with the idea of diagnostic mineralization over structure. It is seen that the average "deep" conductivity which also embraces the shallow layer, has practically the same value as the lowest conductivities encountered in the "shallow" layer. Hence the most anomalous portions of the section are not the conductivity lows but are the high conductivity strips of surface material. If it is argued that the high conductivity strips are mineralized then the mineralization must be a surface phenomenon and can not have resulted from a lower source since the underlying material has a fairly uniform and low conductivity. On the other hand if it is assumed that mineralization is a process whereby the earth conductivity is lowered then the deepest layer embraced in this survey must be uniformly mineralized or (the most likely explana-

tion) it is normal. It is difficult to understand how the large variations in conductivity of the surface layer can be associated with a deep-seated anomaly since the data points strongly to the presence of a

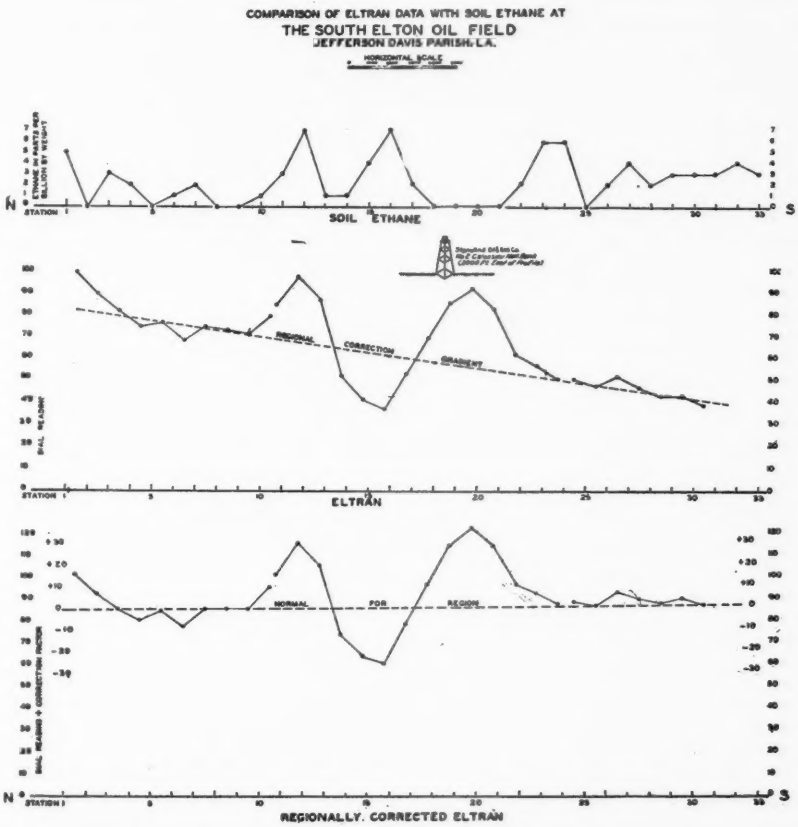

FIG. 6. Reproduction from paper by E. E. Rosaire, "Shallow Stratigraphic Variations Over Gulf Coast Structures," GEOPHYSICS, Vol. III, No. 2 March 1938, p. 108.

comparatively thick layer of uniformly low conductivity immediately below the surface layer.

Fig. 5 shows the data obtained in another north-south line one mile east of that in Fig. 4. This line has characteristics similar to those of the previous line and is shown primarily because it has a length of fifteen miles and exhibits six "shallow" conductivity lows.

Although the surface beds on structure as well as off have probably undergone alteration in some degree due to mineralization, a

more likely explanation of the large conductivity variations here observed or at least a factor to be considered in such an explanation, is the type of deposition encountered in the surface layer. According to Barton,[4] Doering,[5] and Meyer,[6] this layer which is of Beaumont age is not of uniform marine deposition but is in a large part made up of deltaic and lagunal phases.

The writer was not able to find any detailed geological reports covering the South Elton area but of the area west of the Sabine River Meyer[6] states "Barton[4] has shown that the Beaumont of eastern Texas was formed largely by the coalescence of deltas of the Brazos, Trinity, Neches and Sabine Rivers. Low, sandy, dendritically branching ridges have been interpreted as old, abandoned distributaries. These distributaries extend inland almost to the Beaumont-Lissie contact. The Beaumont is not entirely deltaic, however, for marine and lagunal deposits are interstratified with the delta deposits."

Cross-sections given by Doering[5] indicate only the order of Beaumont thickness to be expected at South Elton but that is in the neighborhood of 100′. Meyer[6] further states that "The Beaumont is distinguished from Lissie by its much greater clay content and by the absence of gravel." Since the Beaumont immediately overlies the Lissie these geological data agree in general with the findings in the present direct current survey insofar as they indicate a surface layer of high average conductivity of the order of 100′ deep overlying a thicker layer of relatively low conductivity.

Conclusions drawn from the material presented may be briefly summarized as follows: First, that Eltran and direct current data show good qualitative agreement; second, that the large observed variations in near surface resistivity can hardly be attributed to mineralization emanating upward over structure; third, that the number of anomalies found is so great that their direct association with deep structure is highly improbable.

[4] Donald Barton, "Deltaic Coastal Plain of Southeastern Texas," Bull. Geol. Soc. America, Vol. 41 (1930) pp. 359–82.

[5] John Doering "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," Bull. A.A.P.G. Vol. 19, No. 5 (May, 1935), pp. 651–688.

[6] Willis G. Meyer, "Stratigraphy and Historical Geology of Gulf Coastal Plain in Vicinity of Harris County, Texas," Bull. A.A.P.G. Vol. 23, No. 2 (Feb. 1939), pp. 145–211.

A NOTE ON THE RELATION OF SUDDENLY APPLIED DC EARTH TRANSIENTS TO PULSE RESPONSE TRANSIENTS*

G. E. WHITE†

ABSTRACT

From some work by Carson, the relation between the earth response to a Heaviside function voltage and the response to an impulse is pointed out. A method of obtaining all other electrical measurements from the impulse response is indicated. It is suggested that a new experimental method might yield more accurate measurements of the electrical earth responses than can be had from suddenly applied DC transients, or any of the steady state measurements.

Considerable interest of late has been attached to the results obtained from electrical methods other than the usual alternating current or direct current methods. Some of these methods have measured the responses to a suddenly applied DC voltage, obtaining the significant information from the transient during the buildup to steady state.

One possibility that has been utilized is the connection of four collinear electrodes in the earth, connected as in Fig. 1. Essentially, a voltage supplied by some source, such as a storage battery, is applied between two of the electrodes by closing a switch. The switch may of course be an electronic device. Between the remaining two electrodes is apparatus, such as a cathode ray oscillograph, for obtaining oscillograms or other data on the voltage transient.

Some workers have hoped that what might be termed irregularities in the rate at which this voltage transient builds up to steady state would have some significance in relation to the electrical stratification of the earth. However, the problem of measuring the transient voltages with sufficient accuracy to enable the derivative to be computed has been a barrier to work from this angle, even assuming that the necessary theoretical work could be done.

If the derivative of the voltage transient in question could be accurately measured, it should show in a much clearer fashion any departure from "smoothness" of the transient due to a stratified earth. But, as pointed out, the experimental difficulties of obtaining this from the suddenly applied DC results are practically insurmounta-

* Presented at the Annual Meeting, Oklahoma City, March 21, 1939.

† University of Texas.

ble. However, an inspection of some work by Carson[1] and subsequent workers in the integral equation response of electrical networks leads to some interesting conclusions with regard to obtaining directly the derivative of this particular type of voltage transient.

In Fig. 1, let the voltage between G_3G_4 due to one volt of DC suddenly applied between G_1G_2 at $t=O$ be the function $A(t)$. $A(t)$ is usually called the indicial voltage transfer function. Then, according to Carson, the voltage between G_3G_4 due to any other type of voltage applied between G_1G_2 will be given by

$$F(t) = \frac{d}{dt}\int_0^t f(t-\lambda)A(\lambda)d\lambda$$

where f(t) is the driving voltage, and $F(t)$ is the voltage to be measured.

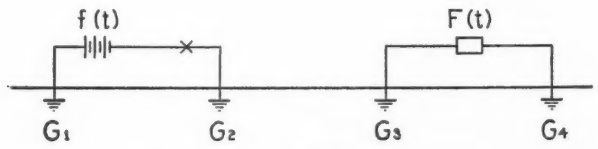

FIG. 1. Typical Electrode Configuration.

Now, suppose that f(t) is a unidirectional pulse of finite time integral, but of extremely short duration, and applied at $t=0$. If the time integral of f(t) is finite, then we can write

$$\int_0^\infty f(t)dt = T.$$

Inserting this in our response equation and allowing the duration of the pulse to approach 0 while holding T constant, we have, if $A(0)=0$,

$$F(t) = \frac{d}{dt}[TA(t)]$$
$$= TA'(t).$$

Now a practical and close approximation to this could be obtained by applying a sharp DC pulse to the earth, lasting, for instance, less than .001 second. The transient then observed would approximate the time derivative of the transient obtained from the suddenly ap-

[1] John R. Carson: Trans. AIEE, 1910.

plied DC case, with the possibility that the approximation might be somewhat in error near the origin. Note that the result is independent of the wave form of the pulse, so long as it is sufficiently short in duration.

The question of course arises as to the amplitude and length this pulse would need in order to give an observable voltage response. Suppose we assume as roughly approximating a practical case

$$A(t) = \frac{30 \times .001}{100}(1 - e^{-500t})$$

where we have measured 30 millivolts due to 100 volts between the power electrodes. Taking the derivative, we have

$$A'(t) = .0003 \times 500e^{-500t}$$
$$= .15e^{-500t}.$$

Hence, we can write

$$F(t) = .15Te^{-500t}.$$

Suppose that f(t) is a pulse of 1000 volts amplitude, flat topped, and lasting .0001 second. Then, $T = 1000 \times .0001$ or .1.

$$F(t) = .1 \times .15e^{-500t} \text{ millivolt.}$$

This calculation is worthless from an analytical standpoint, predicting only the order of magnitude of the results to be expected. It would seem that a definite engineering possibility exists of measuring this type of response, using reasonable power voltages.

Attention should be called to some further interesting facts connected with the function $A'(t)$. Carson has shown that if it is desired to know the response of a network to any electromotive force, however arbitrary, then $A'(t)$ is the necessary and sufficient information for the solution of the problem, provided $A(0) = 0$. As an example, the steady state response to a single frequency driving voltage can be written

$$F(t) = E \sin \omega t \int_0^\infty A'(t) \cos \omega t dt - E \cos \omega t \int_0^\infty A'(t) \sin \omega t dt.$$

Note that the phase shift is implicitly involved in this solution. Phase shift is a difficult quantity to measure in the earth directly, but it is an essential part of the information in any method involving the transmission of earth currents.

If $\omega = 0$, then the above integrals reduce to the DC response, permitting the computation of the usual DC resistivity.

The particular pulse response in question here contains no more information than the step function response; either measured perfectly would contain all the electrical information that could possibly be obtained under the particular electrode configuration of the experiment. The possible advantage of the pulse response might lie in the fact that data can never be taken perfectly, so whatever experimental method yields the most significant data with the least effort should be the most practical. Consequently, some field work along the indicated lines should certainly be done to find whether or not this method might have some advantages over the others in use.

RECENT DEVELOPMENTS IN ELTRAN PROSPECTING*

PAUL W. KLIPSCH†

ABSTRACT

Early difficulties encountered relative to measuring the wave form of the detected potential by means of a predistorted opposing wave have been eliminated by introducing several novelties. These comprise a new mixing circuit, novel means for synchronizing the opposing wave with the detected wave, and simplified predistorting networks. A calibration scheme is outlined to maintain the detection apparatus at a constant level of performance.

A simplified method of measuring the detected wave form obviating the synthetic opposing wave, useful in certain areas, is shown. Essentially it comprises subjecting the detected wave to the further distorting action of a simple circuit, the adjustment of which produces a standard wave shape consisting of straight lines in the oscilloscope. The adjustment of this circuit necessary to bring the wave shape to this standard value constitutes the measure of the time constant of the detected wave.

INTRODUCTION

Eltran prospecting in its inception involved causing an electrical impulse of current to flow in the earth and observing the voltage transient at a distance from the region of current flow.[1] Statham[2] showed a null method wherein two opposing current impulses are generated and the difference between the voltage fields observed, the location and magnitudes being varied until the difference is a null.

West[3] described a method and apparatus in which three novelties were introduced, first, the use of periodically repeated transients to facilitate visual observation, second, the generation within the receiving equipment of a voltage for nullifying the received "signal voltage, and, third, means for synchronizing that locally generated voltage with the current transient.

The null method in one form or another has come into more or less general use. Some of the null methods have been found to involve serious drawbacks but experiments in field trials by Subterrex have resulted in such important improvements that these difficulties have been largely eliminated.

* Read at the annual Meeting, Oklahoma City, March 22, 1939.

† Development Engineer, Subterrex, Houston, Texas.

[1] U. S. Patent 1,911,137 to L. W. Blau.

[2] Louis Statham "Electric Earth Transients in Geophysical Prospecting," GEOPHYSICS I, June 2, 1936.

[3] S. S. West "Electrical Prospecting with Non-Sinusoidal Alternating Currents," GEOPHYSICS III, 4 October 1938.

One of the difficulties was the method of mixing the locally generated voltage with the received signal. West[4] used two grids and a common plate load to mix the signal with the local voltage. Other workers have connected the local wave generator in series with the detection line and indicating instrument. Difficulties in the first case were encountered due to small inequalities of the two amplifier elements, and in the second due to stray capacitances shunting the local generator and indicating instrument since they did not have common grounds.

I

MIXING CIRCUIT

In Fig. 1 is shown the idea used to perform a satisfactory mixing function. The main generator produces a current of rectangular

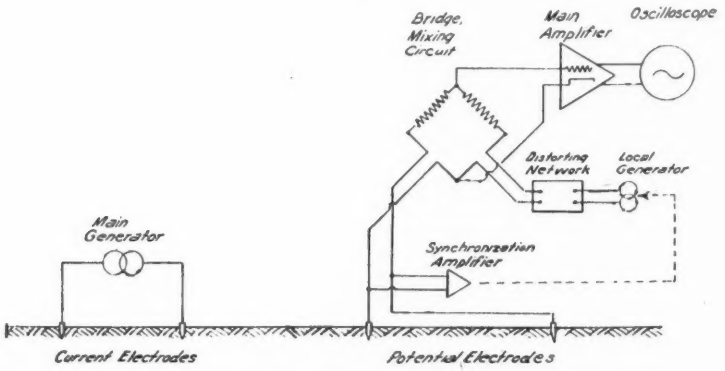

FIG. 1. Eltran system with opposition wave (balancing) generator, showing improved mixing circuit.

wave form. The wave form of the potential between the detection electrodes is to be measured in terms of its time constant, amplitude, indicial response or other characteristics. This detected voltage is amplified in a synchronization amplifier to produce impulses of sufficient amplitude to hold the local oscillator in step with the first increment of the detected wave. The local oscillator is a grid controlled gas filled tube so arranged in its circuit that its wave form is practically rectangular. Thus the wave forms of the local and main generators are similar. The distorting network may be selectively adjusted so that the wave form from the local generator can be made to match

[4] *Loc. cit.*

in shape the wide variety of detected waves. Mixing takes place in the bridge-like circuit in which the two resistor arms shown have values of resistance much larger than the electrode resistance or the internal impedance of the distorting network. Thus the detected wave can not modify the locally generated and distorted wave, nor can the local wave modify the detected wave. They are simply added together, or perhaps we should say subtracted, since the addition properly takes place in inverted relation. When the distorting network produces a wave form of similar shape and equal magnitude to the detected wave, the cathode-ray image becomes simply a straight line indicating the arrival at a null or balance. The operator adjusts the controls consisting of calibrated dials on the distorting network until he obtains a null, and then records the dial settings.

It will be noted that the amplifier, the local generator with its distorting network, and the synchronizing amplifier are all grounded to the same earth electrode. This enables the use of common grounds in the detection apparatus, a common metal cabinet, and all amplifier elements grounded to the metal case and the nearest detection electrode. This contrasts with previous arrangements in which some apparatus had to be grounded at the near electrode and other closely associated apparatus grounded at the far electrode, or else the detected and local wave forms had to be amplified separately before mixing with the result that minute differences in amplifier characteristics would produce marked errors in the wave form measurement.

SYNCHRONIZATION

The synchronization of the local oscillator with the incoming wave was at first a serious problem. More or less accidentally it was found that by operating the synchronization amplifier with abnormally low battery voltages so that amplifier saturation occurs, a higher gain can be used and more positive and accurate synchronization effected. Without saturation, natural earth transients would frequently cause spurious synchronization, and the slope of the detected wave caused a material delay. By using a high gain the initial rise of the detected wave could be used to eliminate the delay, but then the natural earth current transients would be amplified to such an extent that the local oscillator would ignite at times other than at the beginning of the wave to be balanced. Saturation of the amplifier cleared this up to a great extent. Some further increase in effectiveness of the synchronization amplifier was found to occur when a low pass filter was used

between successive stages so that frequencies in excess of about 1,000 cycles are attenuated.[5]

SYNTHESIZING CIRCUIT

A wide variety of distorting networks was tried. The problem, generally, consists in producing from a rectangular wave all shades

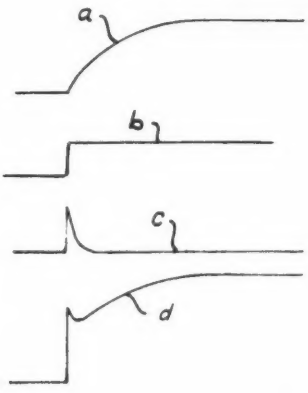

FIG. 2. Components of a typical earth potential transient resulting from square wave current impulse.

of variation including those illustrated in Fig. 2. Some of the first attempts at producing such wave shapes resorted to the circuits shown in Figs. 3, 4, and 5. Each of these fulfilled the requirements in

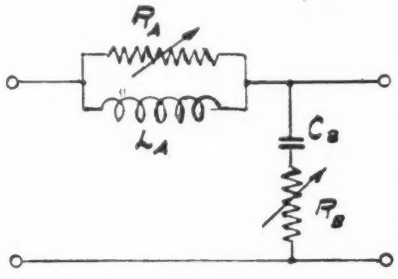

FIG. 3. Early experimental type distorting network.

part, but attempts to combine them to meet all situations resulted in either inoperativeness due to one circuit modifying the performance of an associated circuit, or else the variables became so numerous and inter-related that interpretation became extremely difficult.

[5] U. S. Pat. 2,162,147 to S. S. West.

Figs. 6 and 7 show two circuits which represent very satisfactory means for reproducing, within practical limits, all the wave shapes thus far encountered. As these two circuits are nearly alike in performance discussion will be limited to the circuit of Fig. 6. In this

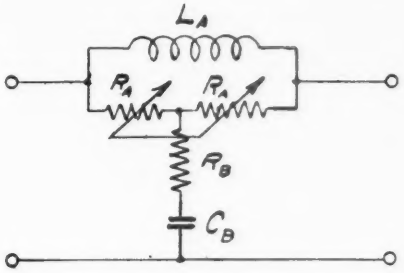

FIG. 4. Early experimental type distorting network.

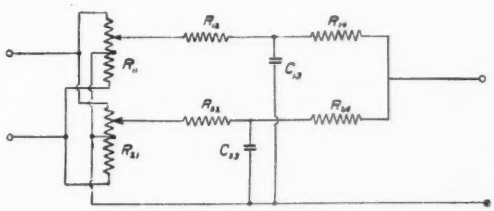

FIG. 5. Distorting network, the adjustments of which correspond 1:1 with parameters in an equation describing the potential transient.

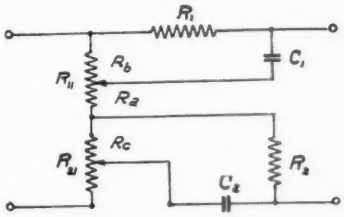

FIG. 6. Distorting network with simpler control than Fig. 5.

figure R_a determines the magnitude of the rectangular component *b* in Fig. 2. The magnitude of resistor R_b determines the magnitude of the *a* component and R_c that of the *c* component. The time constants of *a* and *c* components are determined respectively by R_1 and R_2. Thus with four wave shape controls, in addition to a simple volume or total amplitude control, the entire wave shape may be produced

with sufficient accuracy to measure the shape of waves encountered in field exploration.

CALIBRATION

The synthesizing network just shown has another application. By combining such a device with a low power square-wave generator separate from the rest of the apparatus, a means of calibrating the rest of the apparatus becomes available. A periodic check on apparatus performance is at least useful if not absolutely necessary, and all Subterrex crews have been furnished such calibration apparatus

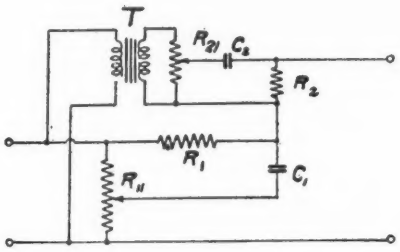

FIG. 7. Alternative form for circuit of Fig. 6; by use of several transformers, more complicated wave forms may be produced.

whereby the regular equipment may be standardized. The calibration apparatus in turn is maintained within close limits by the laboratory.

II

Thus far, the paper has dealt with the measurement of a detected wave shape by the generation of another wave shape and the calibrated adjustment of the generated wave until it matches the detected wave to a close degree of approximation. A radical departure from this procedure is next to be described.

THE "SAWTRAN"

One of the most novel ideas so far introduced in measuring the wave shape distortion has been dubbed the "Sawtran," because of the wave shape produced. In this method, instead of synthesizing a wave form with which to oppose the detected wave to produce a null, the detected wave is subjected to further measurable distortion until a pre-determined wave shape is produced.

In Fig. 8, if a wave of rectangular shape is applied to terminals 11, a zigzag or serrated wave shape is produced at terminals 22. (Assuming that the time constant R.C. is long compared to the period of the

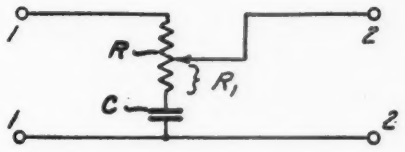

FIG. 8. The "Sawtran" element for producing further transient distortion in the detected wave.

rectangular wave; when this time constant is greater than about 10 times the wave period, and a linear sweep is used for viewing, the saw-shaped wave is composed of nearly straight lines.)

If one of the wave shapes shown in Fig. 2 is impressed on the terminals 11 of Fig. 7, and the slider on the potential divider adjusted, a position can be found in which the resultant wave shape consists of straight lines, and the adjustment of the slider can be used as a measure of the speed of the impressed wave, that is the time constant can be measured.*

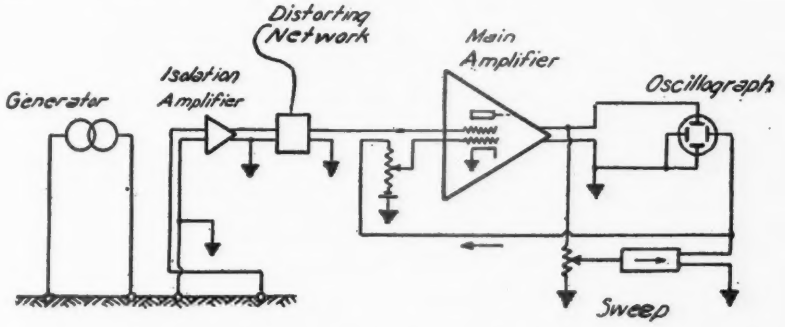

FIG. 9. The complete "Sawtran" circuit.

Fig. 9 shows how the Sawtran circuit is set up. The incremental distorting network of Fig. 7 follows an isolation amplifier, and its output is further amplified for viewing in the cathode-ray oscilloscope. A linear sweep oscillator and sweep lock amplifier are likewise provided. Sweep voltage may be fed into the main amplifier so that

* See Appendix.

the part of the saw wave under scrutiny may be brought to the horizontal thus making the adjustment for straightness, or the balance, more critical.

This method is adaptable to the measurement of a single characteristic of the detected wave, such as the time constant. If the detected wave shape is complicated, the "balance" results in a saw-wave with kinks at the corners. The "best balance," a matter involving to some extent the judgment of the operator, tends to eliminate non-essential features of the wave shape, and to concentrate on a single predominating property of the wave shape. As a single predominant characteristic of the wave form is that which is normally measured and used for contouring, this "Sawtran" is a considerable simplification of the older Eltran technique. The choice between this and the null method is made on the basis of a few trial determinations in a new area when the general complexity of the range of wave shapes encountered are considered. If waves with considerable negative slope are met, the null method is generally to be preferred, but where waves like Fig. 2*a* or *a* and *b* combined are encountered, the simplicity of the Sawtran is a distinct advantage.

III

THE OSCILLOGRAPHIC METHOD

Visual observation of the wave form, before or after balance, affords data only for a written record of the data for each station. It was felt that a photographic record of the wave form was to be desired. Accordingly the cathode ray oscilloscopes were fitted with camera equipment whereby oscillographic records might be attained. An unexpected advantage resulted from this, in that when any electrical noise (natural earth current transients, power and telephone interference and the like) exists, the cathode-ray image shifts about on the screen, but a photograph of a considerable number of repetitions of the image results in a quite accurate picture of the true wave form. The camera lens is stopped down so that each single sweep of the cathode-ray beam creates only a weak image, and then the wave is repeated enough times to build up the image the amount necessary to produce a good picture. Under quiet conditions a sharp picture results; at a noisy location (electrically), the picture of the wave form consists of widened lines with greatest density of exposure along the centers of the lines. The true wave form as thus seen by the camera through transient electrical noise can be quite accurately determined

from such photographs. A study of a large number of these oscillographic determinations has indicated their value in several respects, first, they afford permanent records, second, they serve as checks on data collected by dial readings, third, they offer a means of "seeing" the wave form through a haze electrical noise, and fourth, they can be studied at any time by Fourier Analysis or other techniques either to reveal otherwise unsuspected peculiarities of wave shape or for ordinary measurement of the time constant or other recognized feature.

ACKNOWLEDGMENT

These improvements are the results of the research and development of Drs. Rosaire, S. S. West and S. Bilinsky, and Messrs. W. G. McLarry, R. Saibara, and the writer. Appreciation is expressed for permission by Dr. Rosaire to publish this information.

APPENDIX

The Sawtran circuit of Fig. 7 may be analyzed briefly as follows: If a potential whose wave shape is defined by

$$e_1 = E(1 - \epsilon^{-\alpha t})$$

is impressed on a circuit whose indicial response is

$$A(t) = 1 - (1 - r)\epsilon^{-\beta t}$$

the resultant potential is

$$E(t) = 1 - \epsilon^{-\beta t} + \frac{r - \beta/\alpha}{1 - \beta/\alpha}(\epsilon^{-\beta t} - \epsilon^{-\alpha t})$$

and the adjustment which makes

$$r = R_1/R \text{ or } \frac{1}{R_1 C} = \alpha$$

causes the last term to vanish so that

$$E(t) = 1 - \epsilon^{-\beta t}.$$

If $1/\beta = RC$ is large compared to R_1C and to the period of repetition of the wave, the resultant is the saw-wave referred to in the main body of the paper, and the adjustment R_1C is a measure of the time constant α of the impressed wave. For the detailed mathematical steps in this proof, see V. Bush, "Operational Circuit Analysis," John Wiley and Sons 1932.

A PROPOSED GEOPHYSICAL METHOD FOR ORIENTING CORES*

VICTOR VACQUIER†

ABSTRACT

A new method of orienting cores is suggested, in which a fluid suspension of magnetic particles is made to solidify and adhere firmly to the formation at the bottom of the well. While the substance is still liquid, the magnetic particles line up in the direction of the earth's magnetic field so that upon solidifying a magnetized body is tightly cemented to the rock. The formation is then cored and the top-most core carrying an inclusion of the polarized material is oriented by means of a magnetometer. When such a core is recovered there can be no doubt as to the fidelity of the result.

Although attempts to orient cores have been made since 1844, there does not exist today an entirely satisfactory method for determining the orientation of the dip of buried geologic strata from a single core. It is true that several schemes which have been actually tried out achieved under favorable conditions a certain degree of success. However, none of them has withstood the test of time, for the industry has not adopted yet any one scheme to the exclusion of all others.

The primary requisite of a useful method for orienting cores is that the information obtained be definite. At the present time wildcat drilling is done principally on seismograph prospects, so that at least some information regarding the direction of dip is usually available at the outset. The application of core orientation is thus restricted to the function of providing additional information where it is felt that seismograph results are not reliable, as for example where very steep dips are encountered, or simply to furnish an independent method of measurement. It is doubtful whether a scheme of core orientation will ever be generally adopted for this purpose unless it can be shown that it is more reliable than the seismograph.

The successful mechanical methods of core orientation reached their ultimate development in Macready's device[1] which consists of a core-barrel on which is mounted a surveying instrument consisting essentially of a magnetic compass, a plumb-bob, and a photographic

* Presented at the Annual Meeting, Oklahoma City, March 21, 1939.

† Gulf Research & Development Company, Pittsburgh, Pa. Published by permission of Dr. Paul D. Foote, Executive Vice-President.

[1] G. A. Macready, Orientation of cores, Bull. Amer. Assoc. Petr. Geol., Vol. 5, 571, 1930.

camera actuated by clock work. In nine years that have elapsed since the publication of Macready's paper his method, ingenious as it is, has been little used by the industry. According to Macready's paper the chief difficulty arose in making sure that the rock in the core barrel remained undisturbed in azimuth while drilling was in progress. If the column of the core fractured at its base the core barrel would rotate slightly, making it difficult to correlate the photographs with the discontinuities thus produced. This makes a relatively high percentage of doubtful measurements unavoidable, and furthermore in any particular case the reliability of the determination is difficult to estimate unless several runs are made. Macready's device is thus liable to serious error, even though it has measured dips successfully.

The polar core orientation developed by Herrick and Lynton[2] is open to the same fundamental objection. Its operation is restricted to formations which possess magnetic polarization and depends in addition on other factors the influence of which it is difficult to estimate. The origin of the magnetic polarization of core-samples of sedimentary rock is not clearly understood. In their publications[2] Herrick and Lynton ascribe the origin of the magnetic polarization of sedimentary rocks to the directive force of the earth's magnetic field on the magnetic particles during the deposition of the sediment. If this is the case then the sediment should likewise possess a vertical magnetization because in North America the vertical component of the earth's magnetic field is greater than the horizontal component. The recent work of McNish and Johnson[3] has demonstrated the existence of a vertical magnetization in Pleistocene clay and ocean deposits which is too large to be neglected. The projection of this vertical component onto a horizontal plane which will occur when the sediment is tilted adds vectorially to the projection of the original horizontal magnetization of the formation, so that in general the radial magnetization of a core extracted from a dipping formation is not necessarily directed along the magnetic meridian. Furthermore, McNish and Johnson have found in Pleistocene clay departures as large as 35°

[2] N. H. Herrick, U. S. Patent No. 1,792,639, Feb. 17, 1931. E. D. Lynton and N. H. Herrick, U. S. Patent No, 2,104,752, Jan. 11, 1938.

E. D. Lynton Laboratory Orientation of Well Cores by their Magnetic Polarity, Bull. AAPG., Vol. 21, pp. 580–615 (1937). E. D. Lynton, Recent Developments in Laboratory Orientation of Cores by their Magnetic Polarity, Geophysics, Vol. 3, pp. 122–129 (1938).

[3] A. G. McNish and E. A. Johnson. Magnetization of Unmetamorphosed Varves and Marine Sediments, Ter. Mag. Vol. 43, pp. 401–407, 1938.

from the present magnetic declination. In addition to this uncertainty, the stability of the magnetism of sediments varies greatly from rock to rock, and the influence of the magnetic field of the drilling tools under conditions of severe mechanical shock encountered in drilling cannot help altering, in many cases, the original direction of the magnetization. All this does not mean that the method is considered to be without commercial value. Because of its simplicity and low cost it is definitely worth while to establish the degree of its reliability by a statistical study of its successes and failures. It should be realized, however, that by the very nature of the method, it is bound to give a certain percentage of faulty measurements.

The purpose of this paper is to propose another scheme of core-orientation[4] the essential characteristic of which is that it either gives the correct answer or fails completely, the two possibilities being immediately distinguishable at the time the cores are extracted from the well. Briefly, the method consists in attaching to or diffusing into the rock a substance which, after a short time, solidifies and acquires a permanent magnetic moment in the direction of the earth's magnetic field. The formation is then cored with customary tools and the top portion of the core containing the polarized magnetic material is tested with a portable magnetometer. The obvious objection that the success of this method depends upon the recovery of the first few inches of the core is not felt to be as serious as one might be led to believe at first, because by means of wire-line coring it is now possible to ascertain not only the presence of dipping bedding planes, but also the mechanical properties of the formations encountered by the drill. It is thus possible to select for orientation formations which are sufficiently well consolidated to assure a high percentage of recovery.

There is a variety of magnetic materials which might be introduced into the rock. We need not be afraid of the influence of artificial magnetic fields on the polarized material because magnetic alloys possessing coercive forces of several hundred oersteds could be used. In the process under consideration the magnetic material is in the form of very small particles, say about 1 μ in diameter dispersed in a fluid which is capable of solidfying and of firmly adhering to rock. This fluid may be quick-setting cement or an organic silicate[5] which, upon reacting with the water in the well, or with the connate water in porous formations, forms a tough gel.

[4] Victor Vacquier, U. S. Patent No. 2,140,097, Dec. 13, 1938.

[5] Deering and Reed. Alkylorthosilicates. Jour. Am. Chem. Soc. Vol. 50, p. 3058, 1928.

The procedure by which the fluid suspension of magnetic particles may be introduced into the formation has not been worked out in detail, but the following method is being seriously considered. It is assumed that by means of wire-line coring we have discovered that the drill is passing through a formation showing dipping bedding

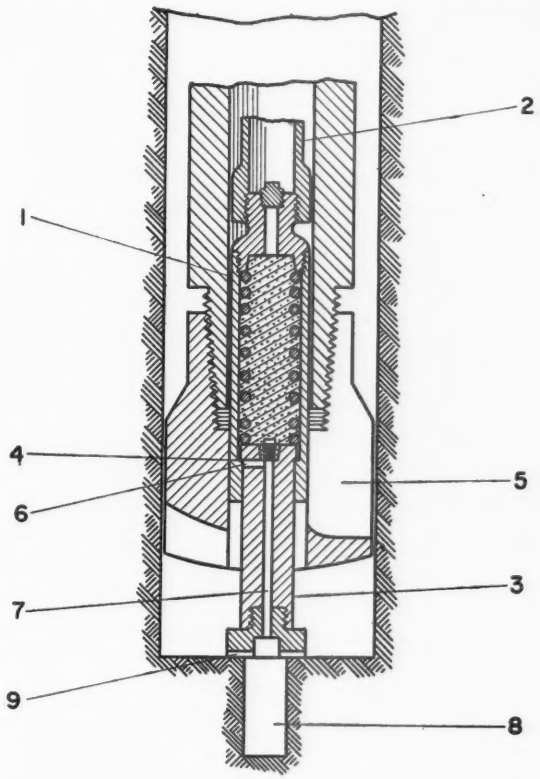

FIG. 1.

planes and that this formation is likely to yield a recoverable specimen. A special tool is lowered on the wire-line by means of which a hole about one inch in diameter and three or four inches deep is drilled into the floor of the well. Upon completion of this pilot hole the tool is replaced by a device capable of injecting the magnetic suspension. Fig. 1 gives a general idea of the construction and operation of this container. It consists of a hollow cylinder 1 attached to the retractable member 2 of a conventional wire-line coring outfit. The bottom of cylinder 1 is closed by a piston 3 which is prevented

from falling off by collar 4. As in the case of standard wire-line tools, the retractable member locks itself to the main tool when the drill-bit 5 is off bottom. The tool string is then lowered very slowly. As the piston is pushed up into the cylinder it uncovers port 6 and the magnetic suspension is squirted through duct 7 into the hole 8. The mud previously held in the hole and the excess of the injected fluid pass through ports 9 in the shoe of the piston. The tool string is now slowly lifted so as to suck back into the container the largest part of the injected fluid which spread out around the piston shoe. The tool string is then pulled out and standard coring tools capable of extracting a core of large diameter (say, 3 inches) are dropped into the well. In the meantime the magnetic particles in hole 8 have acquired their orientation and have become fixed to the rock, so that coring can proceed without further delay.

The main objection against the procedure outlined above is that a round trip down the hole is made for the sole purpose of recovering the first few inches of the core, and it is feared that the process might have to be repeated several times before a satisfactory specimen is retrieved. On the other hand, the possibility of performing all the necessary operations by wire-line should not be overlooked. Off hand it seems that the small size of the wire-line cores will necessitate the reduction of the diameter of the pilot hole to about half an inch or less and it is felt that for this reason the percentage of recoveries will be considerably smaller than if conventional coring tools are used. It should be remembered, however, that many wire-line attempts could be made in the time required for a round trip, and that therefore a greater number of failures can be allowed. Further consideration of these practical matters will have to wait until the scheme is given a trial. It is quite possible that better methods of carrying it out can be devised, and that the difficulties mentioned above will be found less formidable in the course of engineering development than they appear at present.

The question of how cheap a method for orienting cores should be before it can be adopted is rather difficult to answer. It is not very often that a considerable amount of money, say the cost of another well, can be saved by its application. However, when such an opportunity arises it is felt that the actual cost of orienting the dip which might be equivalent to making four or five round trips down the well, is really insignificant, as long as the information obtained can be relied upon. Neither the Macready core-barrel nor the Herrick-

lynton scheme are sure fire. The former is predicated on pulling pipe for each trial, while the latter, as far as published information allows us to judge, has not been used on wire-line cores. The method here proposed does not seem therefore to be much more expensive to use, and in addition offers the possibility of obtaining unambiguous data while carrying out all the steps involved in its operation through the drill-pipe.

In conclusion I wish to thank Dr. E. A. Eckhardt for his constant encouragement and to express my gratitude to Dr. Paul D. Foote and Dr. B. B. Wescott for the guidance they gave me in the prosecution of this problem.

DISCUSSION

We have read with interest the author's proposed ingenious method for orienting cores in a drilling well, but certain practical difficulties would have to be overcome in applying it:

1. It would be no easy matter to drill a 1″ diameter pilot hole in the bottom of an oil well.

2. The bottoms of most holes that have been drilled to any depth are usually covered with steel fragments, worn or broken off the bit, and with magnetite grains sorted out of the cuttings because of their desnity. We have repeatedly found such material in the mud coating ordinary cores, which prevents them from being oriented unless a considerable amount is ground off to present a surface absolutely free of all foreign substances. This mixture of cuttings and magnetite would be fixed in the pilot hole by the cementing composition and should give results more interesting than usable.

3. The magnetic composition introduced into the pilot hole would have to remain very fluid for several hours and then set quickly. The directive force of the earth's field is very weak, and could not overcome much viscosity or shearing strength in a short time.

4. Assuming that the practical difficulties can be overcome and the method made to work with exact accuracy as far as magnetic orientation of the sample is concerned, there would probably still be an uncertainty of 10° to 15° in determining the direction of dip on the 2″ length of beds exposed in a core. Precise accuracy in one part of the operation only is useless.

In the Herrick-Lynton method of orienting cores by their residual magnetism, we have two very considerable advantages not enjoyed by other methods, (1) the method does not interfere with the drilling of the well, and (2) the choice of suitable cores on the surface as to dip and mineral grain contents. Any method which delays the drilling of a well is immediately an item of great expense.

Whereas the Herrick-Lynton method of core orientation is restricted to formations possessing magnetic polarization, our experience over a period of years indicates that 80% of the cores from a drilling well possess such polarization. In California, the only formation which does not give us polarity is the diatomaceous shale of the Monterey, while of course the limestone, anhydrite and dolomite formations of the Mid-Continent area also have proven unworkable in their pure states. However, results can be obtained where these formations are interbedded with shales or sands which do carry heavy minerals.

Regarding the author's remark that the origin of magnetic polarization in the sedimentary rocks is not clearly understood, we know from practical experience with a large number of outcrop samples that the magnetic properties in those outcrop samples lined up with the earth's magnetic field as it is at the present time, because the direction of dip of the samples as determined magnetically checked the actual direction of dip measured in the field after correcting for the magnetic declination of the areas in which the samples were taken.

The author's comments regarding the vertical component of the earth's magnetic field are sound. We take this into consideration when correcting for results, as well as the deviation of the hole if any is present.

As regards the influence of the drilling tools on the residual magnetism in cores: Experiments on magnetism in core barrels show no transverse field across the core at the bottom of the barrel. The magnetic lines of force through a core barrel are longitudinal and this type does not seem to change the residual polarity in a core. Furthermore, the practical results we have obtained from this type of core orientation would indicate this effect, if present, is negligible as far as distorting the residual field in the minerals is concerned.

We are not familiar with the work of McNish and Johnson (Ter. Mag., Vol. 43, pp. 401–407, 1938), so are not qualified to remark on the departures as large as 35 degrees from present magnetic declination on Pleistocene clays, which the author mentions.

The author states that the Herric-Lynton method has not been used on wire line cores. We wish to point out that approximately half of our work is done on wire line cores of $1\frac{1}{4}$ to $1\frac{1}{2}$″ diameter; in fact, some work has been done on diamond drill hole cores of 1″ to $\frac{7}{8}$″ diameter. Wire line cores do not seem to offer any difficulties, as 80% or more of the cores have enough residual polarity to make them workable.

The author's proposed method is a definite advance in the science of orienting cores in the hole provided the difficulties mentioned at the head of this discussion can be overcome. The first step toward surmounting them is to recognize and face them, which is the only reason for stating them here.

E. D. LYNTON*

* Standard Oil Company of California.

AUTHOR'S REPLY

The questions raised by E. D. Lynton can be answered as follows:

1. The matter of drilling a pilot hole 1-in. in diameter at the bottom of an oil well has been discussed with production engineers and has been declared feasible, but it is admitted that there are difficulties to surmount.

2. The presence of steel fragments or of magnetite grains at the bottom of the hole is not objectionable thanks to the remarkable magnetic properties of modern permanent magnet alloys which can be used as the active constituent in the plug. It should be kept in mind that the magnetic particles are to be artificially magnetized before they are mixed with the cement, and that the coercive force of these small magnets can be chosen to be ten times greater than that of any contaminating substance encountered in the well. The specimen, after coring, can be thus subjected to a demagnetizing field which would demagnetize magnetite and steel fragments but which will not affect the magnetization of the particles. We have in our laboratory a plaster of Paris block containing such particles, and we have not been able to change its direction of magnetization by magnetic fields as great as 200 oersteds.

3. Numerous laboratory tests have shown that as long as the matrix material is just barely fluid enough to pour, the substance to be introduced into the pilot hole acquires in less than three minutes under the influence of the earth's field a magnetic polarization several hundred times the average magnetic polarization of sedimentary rocks.

In regard to the origin of the permanent magnetization of well cores, the evidence is conflicting. McNish and Johnson have shown that the magnetization of unconsolidated glacial clays is sufficiently different from the present direction of the earth's field to suggest that these clays have recorded the direction of the geomagnetic field at the epoch of their deposition. Recently these investigators have found variations of declination amounting to 50°, recorded in New England varves. This work actually supports Herrick's hypothesis (U. S. Patent 1,792,639) that sedimentary rocks have acquired their magnetic polarization from the directive action of the geomagnetic field on magnetized mineral grains as the latter settle in quiet water. When subsequently the sediment is tilted, its magnetization vector is tilted along with it; and, since in middle latitudes this vector possesses a large vertical component, an elementary calculation shows that the direction of dip can not be determined simply by finding the orientation of the radial component of magnetization of a core. The contribution of the component of magnetization normal to the bedding planes to the radial magnetic moment of the core can not be corrected for unless the direction of the total magnetic vector with respect to the geometric axes of the core is known. Since the Herrick-Lynton method does not measure the magnitude of the magnetic moment along the axis of the core, it does not supply this information. It thus becomes necessary to assume that the original direction of magnetization such as postulated by Herrick and measured by McNish and Johnson has been erased, so to speak, by physical and chemical changes which the sediment underwent since its deposition or by the action of the drill, for otherwise Mr. Lynton would not have found the horizontal magnetization of his dipping outcrop specimens directed along the magnetic meridian. In this connection it should be noted that the effect of weathering on the direction of the remanent magnetization of rocks has not been studied and that until this is done measurements on outcrop specimens are of doubtful significance. Furthermore, laboratory experiments show that magnetic fields only ten times greater than the earth's are sufficient to alter permanently the magnetization of well cores. Much more intense magnetic fields prevail in the vicinity of the drill bit; and even though the magnetic field of the drill bit is vertical, the susceptibility of stratified rocks is usually anisotropic. Hence in cores possessing dip a vertical field can produce a radial component of magnetization. In view of these considerations, it is rather remarkable that the remanent magnetization of well cores can be used for their orientation.

V. VACQUIER

DISCUSSION AND COMMUNICATIONS

To the Editor:

DEAR SIR:

In GEOPHYSICS, Vol. IV, No. 3, July 1939, p. 225, in discussing Dr. Horvitz' paper on Geochemical Prospecting, Mr. A. J. Teplitz considers that the "halo" pattern (of higher hydrocarbon concentrations in the soil over an oil field) is in direct contradiction with the findings of the Russian workers. Mr. Teplitz goes on to say that "Their (Sokolov and his associates, supposedly,) investigations have always indicated that the higher hydrocarbon concentrations overlie the petroliferous deposits rather than surround them."

In order to keep the geochemical record clear from the start, it may be well to call attention to the following early reports, by Sokolov and an even earlier worker, Laubmeyer. The exerpts were taken from translations furnished the writer by the Engineering Societies Library, in 1936.

"In the Malgobek district the samples were taken along the axis of the anticline as well as along several profiles lying transversely to the extension. The curves of the amounts of heavy hydrocarbons and methane along these profiles intersecting the axis of the anticlinal are shown in Fig. 4.

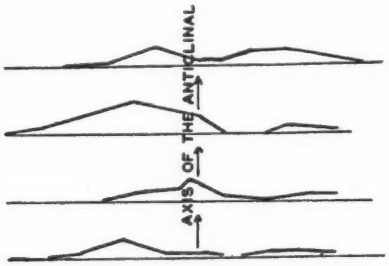

FIG. 4. Curves of the content of heavy hydrocarbons and methane on profiles intersecting the axis of the anticline (Malgobek).

"The gas survey in the Turkeyanui district of the Azneft was made on an area adjoining the Solenoye ozero (Salt Lake) and extending from it in the south-south-easterly direction to the shore of the Caspian Sea. The survey was made according to the surface scheme, whereby the points at which samples were taken were 200 meters apart, while the profiles were similarly spaced 200 meters from each other.

"The results of the analyses are given on the gas-survey map (Fig. 5) and on the profile along the axis (Fig. 6).

"In Fig. 7 the map of the gas survey at Ishimbayevo[4] is shown, data obtained with the field apparatus. From this map it is seen that the maximum content of hydrocarbons occurs on the left bank of the Belaya River. This region of a high volume of hydrocarbons is bordered by one of a somewhat lower volume which is followed by one of a still lower volume and, finally, the westernmost part of the surveyed area is characterized by the lowest volume of hydrocarbons.

[4] The work was carried out by the chemist P. P. Kruglyakova (analyses), and the geologists V. Semin and V. Smekalin (taking of samples).

"In the center of the region of maximum hydrocarbon content a relative minimum occurs, in which the hydrocarbon content has the same value as in the zone which borders the region of maximum content.

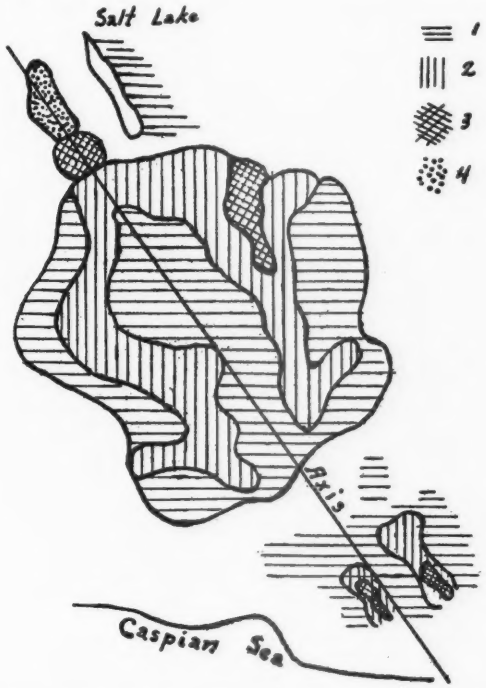

FIG. 5. Results of analyses given on the map of the gas-survey (Turkeyanui). Methane content: 1—less than 0.0005 per cent; 2—from 0.0005 to 0.002 per cent; 3—from 0.002 to 0.0025 per cent; 4—more than 0.0025 per cent.

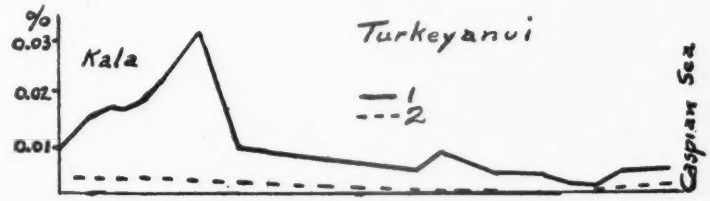

FIG. 6. Results of analyses represented on the profile of the axis. Average hydrocarbon content along the axis of the Turkeyanui structure: 1—heavy hydrocarbons; 2—methane.

"Our attention is attracted by the fact that this relative minimum within the region of the maximum hydrocarbon content coincides with the western dome of the Ishimbayevo field. The western dome is considerably more gas bearing than the eastern dome

located on the right bank of the Belaya river; hence the high hydrocarbon content in the soil air on the left bank, on which the western dome is situated, is in agreement with actual conditions and confirms the basic assumptions of the gas survey.

"At the same time we see from the map that the region of high hydrocarbon content extends over a considerably greater area than the oil deposit. This circumstance is not surprising, since the gaseous and vaporous hydrocarbons not only progress vertically upward from the oil deposit but also spread horizontally. The distribution of hydrocarbons over an area considerably greater than the projection of the area of the oil deposit on the surface of the earth is also observed in other districts; this is seen from the gas-survey maps of the Kala, Turkeyanui and Malgobek districts.

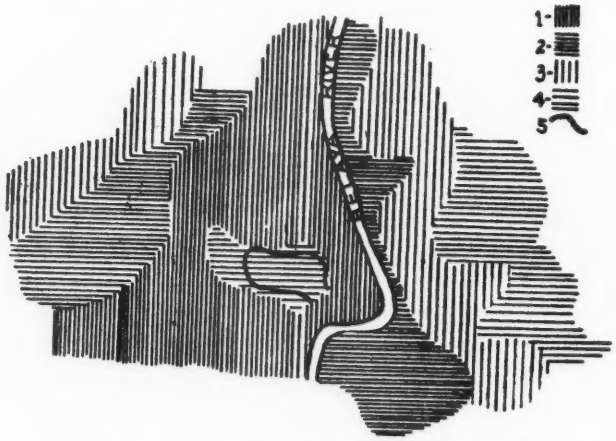

FIG. 7. Map of the gas survey of the Ishimbayevo district. Carbon dioxide content after combustion of the hydrocarbons: 1–0.01 per cent and more; 2—from 0.007 to 0.01 per cent; 3—from 0.005 to 0.007 per cent; 4—less than 0.005 per cent; 5—contour of the oilbearing capacity of the limestones of the western dome.

"The western dome of the Ishimbayevo field is situated in the center of maximum hydrocarbon content, which extends eastwards and reached the eastern dome, where the hydrocarbon content becomes lower."

Summary of the Experimental Work on the Gas Survey V. A. Sokolov. Neftyanoye Khozyaystvo, Vol. 27, No. 5, 1935, pp. 28–34.

Again, even earlier we find:

"In what follows a survey will be briefly given, which was made on an oil deposit near Hannover. In this survey the question was one of determining the concentration of hydrocarbon and the trend of the curve of concentration as the survey stations moved away from the deposit. Fig. 2 shows the situation of the oil occurrence with the necessary geological data and a schematic cross-section. At the same time, the stations which we surveyed are recorded on it. The concentration curve is shown below. The stations of the second profile survey are projected onto the first profile, in order to get comparable results of the measurements. The maximum hydro-carbon value here corresponds to a dilution of the order of $1:10^6$. The main result consists in showing that hydrocarbon gases actually occur above a deposit of hydrocarbons and that

the trend of their concentration also can be determined measurably, and that at sufficient distance from the deposit the amount of CH_4 in the soil air is nil. This survey was well confirmed by borings made later, was repeated about a year later

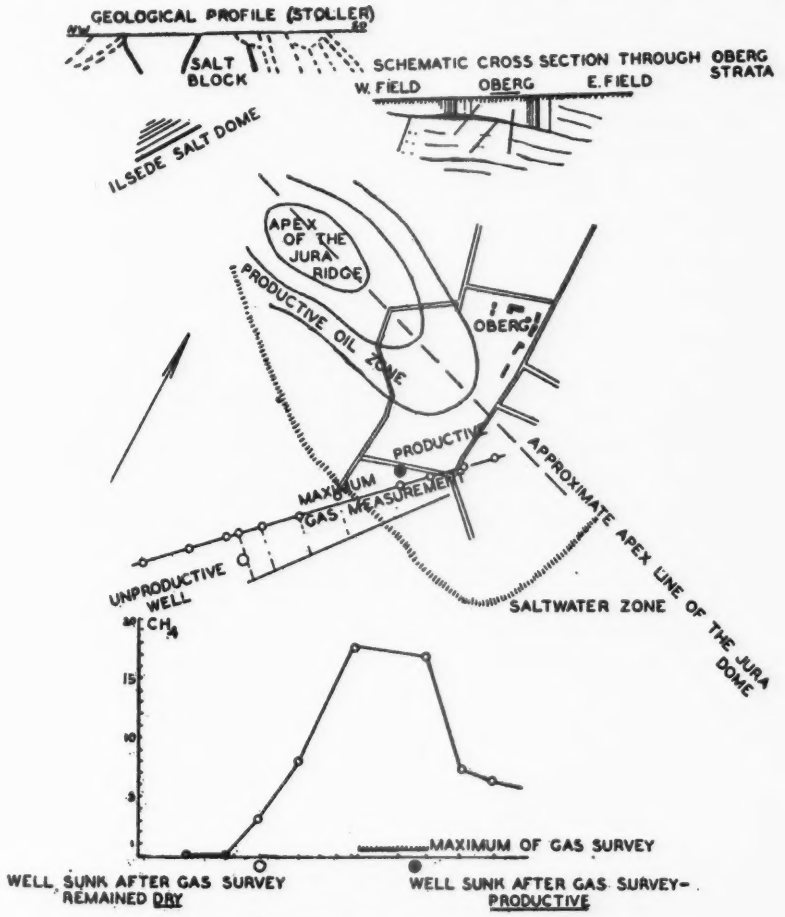

FIG. 2. Gas survey at Oberg, Hanover, Place, geologic and schematic profile and curve measured.

and was also confirmed by the detailed data then obtained. Those boreholes which were drilled outside the maximum concentration did not strike oil, while the borings in the region of concentration did. It was remarkable that the amount of CH_4 in the soil air in the neighborhood of the producing wells diminished sharply; the only explanation of this fact is that the diffusion of gas into the soil air near the wells became less because the gases here took the easier path of escape through the well and the openings in the surrounding strata caused by the drilling."

A New Geophysical Prospecting Method, Especially for Deposits of Hydrocarbons. G. Laubmeyer. Petroleum I, Vol. 29, No. 18, 1933, pp. 1–4.

In the writer's opinion, the "halo" phenomenon was presented in the experimental work of these earlier workers. It may be that similar concentration patterns were observed in other cases, and explained away quite satisfactorily, as in the cases above.

However, Dr. Horvitz was the first to establish and recognize the phenomenon experimentally, and to challenge the theoretical pattern which had been accepted up until then. In so far as the writer is concerned, it was a great shock when Dr. Horvitz reported this type of concentration pattern even at the recently dscovered Hastings oil field.

If agreement with the work of earlier investigators is a criterion, then Dr. Horvitz's work will probably be found more readily acceptable. Since that agreement, however, is with work which the earlier investigators considered questionable, or not truly representative of actual conditions, a dilemma confronts some of us. How much longer shall we continue adherence to a theory whose proponents themselves report contradictory data? Isn't it about time that data be presented, in support of this (non halo) theory, which are comparable in accuracy and extent to that data which show halo around production?

Mr. Teplitz also comments that "Russian research workers have been engaged in geochemical prospecting for almost ten years, but have not yet reported any discovery of petroleum by these means." The writer considers it inconsistent to comment adversely upon prospecting which has failed to yield economic results of value, and then to use that work as a yardstick by which to question results which have yielded economic results of value. It would be far more consistent to question the premises upon which the ten years unsuccessful work was based.

If that latter course is pursued, then the "ten year failure" is explained, for our actual experience has shown that wells located on locally high soil concentrations of hydrocarbons tend to be nonproductive, *for the halo marks the outer limits of production.*

The writer has no intent to decry the work of the earlier investigators, for he appreciates only too well the "sales resistance" which they had to undergo in their pioneering. They can hardly be blamed for leaning too heavily upon their "theory," in view of the fact that the objections to the "halo" pattern (even now so general and in the face of better field techniques) are based upon disagreement of that phenomenon with that same accepted theory.

E. E. ROSAIRE
Subterrex
Houston, Texas

Aug. 1, 1939

To the Editor:

I wonder if as Editor of GEOPHYSICS you will give us your cooperation in a project being undertaken by a Committee of which I am Chairman. This is the Committee on Geophysics Education of the Mineral Industry Education Division of the American Institute of Mining and Metallurgical Engineers. The Committee was organized a little over a year ago, for the purpose of conducting an enquiry into the present methods of teaching geophysics and the status occupied by such courses in university curricula.

Last year we undertook the task of circularizing a large number of universities in

the United States and abroad for the purpose of learning how the subject is actually being taught at the present time. The report covering the activities of this Committee for last year is now available to all who are interested if they will write to the headquarters of the American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York City.

Having thus obtained a perspective of present teaching practices, we believe the next thing is to find out how geophysics graduates evaluate their own training and what the employers of geophysicists think of the academic preparation now available.

In order to get expressions of opinion we are about to circulate a questionnaire to all practicing geophysicists, consulting geophysical companies, and employers of geophysicists of whom we have any knowledge. I should therefore like to present an urgent plea that all who receive these questionnaires give us their wholehearted cooperation by filling them out promptly and completely and returning them to the Committee. We also will be grateful for extended opinions expressed in letter form.

In such a task it is inevitable that geophysicists and companies who should receive this questionnaire will be overlooked. I therefore hope that any who do not receive a questionnaire will write in and request it, for which purpose they should address the writer, who is Chairman of the Committee, at 330 Bay Street, Toronto, Ontario.

Will you be good enough either to publish this letter and second its plea yourself, or write an item yourself covering the subject matter and urging cooperation of all S.E.G. members. This is a project which it seems to me is one requiring the cooperation of the A.I.M.E. Committee and the S.E.G. if it is to achieve the maximum benefit for the profession of geophysics.

I assure you that we will be most grateful for your help and cooperation.

Yours very truly,
SHERWIN F. KELLY, *Chairman,*
Committee on Geophysics Education

330 Bay St.,
Toronto, Canada
July 5, 1939

To the Editor:

In his article on "Concentrations of Hydrocarbons in the Earth, GEOPHYSICS, July 1939, Mr. E. McDermott says "it is known that ethylene in the presence of chlorine, and especially aluminum chloride, will polymerize even at a faster rate." On page 198, the statements are made "based on the assumption that the wax is formed from ethylene in the presence of chloride and sunlight, this is not surprising" and, also, "That ethylene in the presence of chlorine will polymerize was demonstrated in the laboratory by bubbling the gas through a concentrated salt solution for two days."

A different type of reaction between ethylene and chlorine is described by the literature, as follows.

"Ethylene gas is colorless and possesses an ethereal odor. It is extremely explosive when mixed with air or oxygen. Unlike methane, it combines directly with chlorine and bromine to form addition products. Thus, it reacts with chlorine to form ethylene chloride ($C_2H_4Cl_2$), an oily liquid long known as Dutch liquid because it was first prepared by four Dutch Chemists:

$$C_2H_4+Cl_2\rightarrow C_2H_4Cl_2$$

Since ethylene has the property of forming addition compounds, it is called an unsaturated compound."[1]

"The halogens add to ethylene, chlorine with explosive violence if the mixture of the two gases is illuminated, slowly if it is diluted with inert gas or if it is kept in the dark. Bromine adds slowly when ethylene is bubbled through liquid bromine, and iodine slowly when the gas is bubbled through an alcoholic solution of iodine, the addition compound separating out.

$$CH_2=CH_2+Cl_2 \rightarrow CH_2\ Cl\ CH_2\ Cl$$
$$CH_2=CH_2+Br_2 \rightarrow CH_2\ Br\ CH_2\ Br$$
$$CH_2=CH_2+I_2 \rightarrow CH_2\ I\ CH_2\ I$$

The chloride and bromide are stable but the iodide is not. It dissociates into iodine and ethylene. In reaction products of this type the halogen atoms are attached to adjacent carbons."[2]

On page 200, the statements are made that "the chlorine content is even more abundant than near the surface,"—and—"as a result of the chlorine present the unsaturated hydrocarbon gases will have an opportunity to polymerize to a greater degree than otherwise." On page 203 a similar statement is made "It is due to the presence of chlorine, and not mere coincidence, that oil is almost always found in marine sediments."

Chlorine is a heavy green gas, and which is extremely reactive chemically. Sedimentary chlorine, of natural origin, and in appreciable amounts, would represent a very unusual set of circumstances.

Yours very truly,

E. E. ROSAIRE

Sept. 22, 1939

[1] The Romance of Chemistry. William Foster (Prof. of Chemistry, Princeton University) 1927, pp. 370–371, The Century Company, N. Y.

[2] Organic Chemistry. Howard J. Lucas, 1935. American Book Company.

REVIEW OF RECENT PUBLICATIONS

Texas Oil and Gas Since 1543. C. A. Warner. Gulf Publishing Company, Houston, Texas, 1939. 487 pp.

Since 1923, when applied geophysics was first introduced into the U. S. A., the number of geophysicists in active practice has increased tremendously. By far the greater number of these technicians were drawn from schools and professions where oil was something to be bought rather than a natural resource to be found.

For the exploration geophysicists, then, Mr. Warner's book is quite timely. True, the author devotes no great attention to geophysics, mentioning the subject in only ten pages out of the three hundred and forty odd pages of text, and not at all in the bibliography. After all, 1923, is but one third of the way back to 1901, and, of course, not much more than a negligible portion of the way back to 1543.

On the other hand, the picture presented as a whole shows the results of continuous exploration effort over the State of Texas, which, in the period of time covered by the author, has furnished not only the largest oil field in the U. S. A., but the greater part of the reserves established in the country to date.

For those of us whose perspective is limited, either because of unduly short past experience, or because of specialized past interests, the panorama as presented by Mr. Warner is required reading. Many of our membership will probably be surprised to find out the relatively limited part that geophysical exploration has played in the petroleum history of Texas. Though the author makes no effort to develop the point, the reader will reach the conclusion that the reflection seismologists were not the first of the "fair haired" lads in Texas exploration. There were giants in those days, too.

E. E. ROSAIRE

June 28, 1939

Physics of the Earth—VIII, Terrestrial Magnetism and Electricity, Edited by J. A. Fleming, McGraw-Hill Book Co. Inc., 1939. xii+794., $8.00.

This book is a continuation of a series of related monographs* prepared under the direction of various committees of the National Research Council. In common with the other volumes in the series "Physics of the Earth," the aim has been to provide a reference rather than a text book. It covers the broad field of terrestrial magnetism and

* The following complete list of these monographs will be of interest. They are published as bulletins of the National Research Council and are obtainable from the Publication Office, National Research Council, Washington, D.C. Prices quoted are for cloth covers, paper covers at slightly reduced figures. Remittance should accompany order.

No. 77	Volcanology	77	pages	$1.00
No. 78	The Figure of the Earth	286	"	3.50
No. 79	Meteorology	289	"	3.50
No. 80	The Age of the Earth	487	"	5.00
No. 85	Oceanography	581	"	5.00
No. 90	Seismology	223	"	2.50

An additional new volume published by McGraw-Hill Book Company is entitled, Internal Constitution of the Earth, 413 pages.

electricity and is a compilation of the work of fifteen individuals each capable of authoritative discussion of the particular subjects assigned to them.

Because of the interrelation of the subject matter handled by the several authors, some overlapping is unavoidable. However, this has been reduced to a minimum and what has remained must be considered advantageous since it cannot be considered repetition. Rather it serves to provide different approaches to the subject, bringing out some differences of opinion regarding controversial matter and emphasizing those phenomena which, even today, have no satisfactory explanation.

This book is not for the exploration geophysicist whose interest is confined to the scope of prospecting problems, except insofar as a knowledge of measuring technique and equipment used in the study of terrestrial magnetism and electricity, and adequately presented in this volume, may be of direct value to him. On the other hand your reviewer is confident that anyone having a normal scientific interest in the broader aspects of geophysics will find this book both instructive and thought provoking. It is written and profusly illustrated in such a manner that a specialist's knowledge of the various subjects is not required to obtain instructive information and a clear comprehension of the unsolved problems in this field. On this basis it is recommended to readers of GEOPHYSICS.

In view of the scope of the volume it is impossible to present a brief resumé. However, it is believed that an outline of the contents is not only of interest but well warranted and with this in view the following is submitted.

Chapter I—The Earth's Magnetism and Magnetic Surveys. By J. A. Fleming. Pp. 1–58.

This chapter covers the early history of magnetic surveys, secular variations, diurnal and other periodic variations and correlation with solar-day, lunar-day, solar-activity, etc.

Chapter II—Magnetic Instruments. By H. F. Fleming, J. A. Fleming and H. E. McComb. Pp. 59–109.

Discussion of instrumental requirements, design and modern practice at magnetic observations.

Chapter III—Magnetic Prospecting. By C. A. Heiland. Pp. 110–148.

Outlines applications of magnetic prospecting, instruments used, corrections applied and a brief consideration of interpretation and results of a few typical cases.

Chapter IV—Atmospheric Electricity. By O. H. Gish. Pp. 149–230.

Covers an historical introduction, general survey, electrical conductivity of the atmosphere dealing necessarily with sources of ionization, ion distribution, potential gradients and periodic and irregular variations. Included is a brief résumé of various attempts to explain the source of a total conduction current between the sub-ionosphere and the surface of the Earth totalling some 1800 amperes and representing approximately 6×10^5 KW of power.

Chapter V—Instruments Used in Observations of Atmospheric Electricity. By O. W. Torreson. Pp. 231–269.

This chapter is devoted to brief but adequate descriptions of apparatus used for measuring potential-gradient and conductivity of the atmosphere, its ion and nuclei content, space-charge and air-earth currents.

Chapter VI—Earth-Currents. By W. J. Rooney, Pp. 270–307.

Discusses natural earth-currents and methods of measurement. The diurnal variations, a general world-scale map of the circulation system represented by and re-

sponsible for the diurnal variation and the close correlation with diurnal magnetic variations, are discussed.

Chapter VII—Causes of the Earth's Magnetism and Its Changes. By A. G. McNish. Pp. 308–384.

The permanent magnetic field of the Earth is subjected to harmonic analysis and a general description of the permanent field is obtained. Results indicate three sources of the observed magnetic force namely; 94% due to causes within the Earth, a portion due to causes outside the Earth and a small portion called the non-potential portion such as would be due to vertical electrical currents passing through the Earth's surface. The reality of the latter two are discussed. There follows a consideration of the periodic and anomalous variations of the magnetic field and the theories devised to explain them.

Chapter VIII—Some Problems of Terrestrial Magnetism. By J. Bartels. Pp. 385–433.

This is essentially a continuation of the material in Chapter VII.

Chapter IX—Radio Exploration of the Earth's Outer Atmosphere. By L. V. Berkner, Pp. 434–491.

The author reviews the data obtained by radio methods in determining the ion distribution in the upper atmosphere and the variations as related to possible sources of perturbations.

Chapter X—The Upper Atmosphere. By E. O. Hulburt. Pp. 492–572.

This chapter deals with the meteorology of the upper atmosphere, radio studies of the ionosphere and theoretical consideration of its structure. There follows a discussion of the electrodynamics of the upper atmosphere and numerous phenomena related thereto.

Chapter XI—The Aurora Polaris and the Upper Atmosphere. By L. Vegard. Pp. 573–656.

Various forms of the aurora, spacial distribution and relation to solar phenomena are discussed. Then follows a discussion of theories regarding the origin of the aurora, its spectrum and interpretation.

Chapter XII—Thunder-Clouds, Shower-Clouds, and Their Electrical Effects. By B. F. J. Schonland. Pp. 657–678.

The author outlines briefly the electric fields and field changes at the Earth's surface caused by thunder-clouds, discusses the origin and distribution of cloud-charges and touches upon various electrical effects associated with them.

Chapter XIII—Bibliographical Notes and Selected References. By H. D. Harradon. Pp. 679–778.

A list of over 1500 references should prove invaluable to anyone wishing to investigate further any specific phase of the subjects covered.

R. D. WYCKOFF

Sept. 20, 1939

Geophysical Exploration of the Ocean Bottom. (Symposium Arranged for The American Geophysical Union) American Philosophical Society Proceedings, Vol. 79, No. 1, April 1939, 144 pp.

The Importance of Geophysics to Submarine Geology. Richard M. Field.
New Methods of Marine Surveying. G. T. Rude.
Present Status of the Problem of Submarine Canyons. H. C. Stetson.

The Technique of Securing Undisturbed Core-Samples of the Ocean Bottom. Charles Snowden Piggott.

The Geological Survey's Work on the Piggot North Atlantic Deep Sea Cores. W. H. Bradley, M. N. Bramlette, J. A. Cushman, L. G. Henbest, K. E. Lohman, P. D. Trask.

Marine Gravimetric Methods and Surveys. Maurice Ewing.

Gravity Anomalies and Island Arc Structure with Particular Reference to the West Indies. Harry Hammond Hess.

The Role of Earthquakes and the Seismic Method in Submarine Geology. N. H. Heck.

Terrestrial Magnetism and Oceanic Structure. John A. Fleming.

This publication is now available from the American Philosophical Society, Independence Square, Philadelphia at 75¢ per copy. Because of the interest displayed in C. S. Piggot's paper at the Annual Meeting, Oklahoma City, March 1939, and the fact that his paper will not be published in GEOPHYSICS because of the previous publication of substantially similar material, the above source is called to your attention.

EDITOR

PATENTS

The following list of U. S. patents issued since January 1, 1939, while not complete, represents a major portion of those pertinent to the art and of interest to exploration geophysicists. The very brief abstracts of the material covered by the patents are presented merely as an indication of the nature of the material covered so that the reader may judge whether further investigation is warranted.*

ELECTRICAL PROSPECTING

U.S. #2,150,517, DAVID SAVILLE MUZZEY, JR., Iss. 3/14/39, Apl. 7/29/38 Assign. Shell Dev'l. Co.

Electrical Exploration Method—A.C. is run through the ground and the D.C., resulting from rectification at stratigraphic boundaries, is measured. A.C. electrodes are fixed while a pair of D.C. electrodes is moved between them to obtain a curve showing variations of the rectification effect. Earth currents are balanced out including natural D.C. and induced A.C.

U.S. #2,153,636, ATSUSHI MATSUBARA, Iss. 4/11/39, Apl. 11/22/34.

Method of Prospecting Underground Ore Bodies—Polarization voltages are measured across potential electrodes while current electrode circuit is interrupted. Potential electrodes are non-polarizing type.

U.S. #2,162,086, JOHN J. JAKOSKY, Iss. 6/13/39, Apl. 2/21/38.

Method and Apparatus for Eelectrical Exploration of the Subsurface—Natural earth voltages from electrodes unaffected by artificial currents are observed while combined natural and artificial voltages are being measured. Natural effect is then subtracted to give desired artificial measurement.

U.S. #2,162,087, JOHN J. JAKOSKY, Iss. 6/13/39, Apl. 7/13/38.

Method and Apparatus for Electrical Exploration of Subsurface—Natural earth current in one electrode measuring circuit is opposed by another current which is varied according to variations of the natural earth currents as determined at a location not affected by the artificial earth current.

U.S. #2,169,685, H. M. EVJEN, Iss. 8/15/39, Apl. 6/8/37 Assign. Shell Devl. Co.

Electrical Method of Geophysical Exploration—Two ground currents are varied in ratio while effect is studied at a distance. Uses either electrodes or loops or combinations. Shows null method. Switching arrangements to interchange electrodes. Frequency and intensity of currents may be varied to study skin effect and departure from Ohm's law.

U.S. #2,160,824, L. W. BLAU, and L. STATHAM, Iss. 6/6/39, Apl. 11/13/36 Assign. Standard Oil Dev'l. Co.

Electric Earth Transient in Geophysical Prospecting—Symmetrical "Eltran" circuits in which electrical asymmetry is detected by observing difference between transient wave forms. Potential electrodes shown inside of, outside of, and at right angles to current electrodes.

* This list and the abstracts were kindly provided by Mr. Gary Muffly and with the permission of Gulf Research & Development Co.'s directors.

U.S. #2,162,147, S. S. WEST, Iss. 6/13/39, Apl. 7/3/37 Assign. E. E. Rosaire.

Means and Method of Electrical Prospecting—Form of square wave transmitted through the earth is compared with a locally generated square wave which is synchronized with it and distorted by a special network to make it similar to the earth wave as indicated by a null method. Earth wave may also be recorded and analyzed. Uses noise filters. Shape of transients or setting of distorting network is criterion in determining earth structure.

GRAVIMETRIC PROSPECTING

U.S. #2,148,678, L. W. BLAU and A. B. BRYAN, Iss. 2/28/39, Apl. 11/8/34 Assign. Std. Oil Dev'l. Co.

Apparatus for Comparing a Plurality of Oscillatory Systems—Gravity differences measured by comparison or measurement of harmonics of pendulum or other vibrating system.

U.S. #2,149,953, A. K. BIRNBAUM, Iss. 3/7/39, Apl. 3/2/36 Assign 1/2 H. C. Cockburn.

Automatic Leveler for Gravity Measuring Instruments—Underwater chamber for self-leveling of gravity instrument on gimbals.

U.S. #2,150,405, S. A. SCHERBATSKOY, Iss. 3/14/39, Apl. 1/29/38 Assign. Eng'r. Labs., Inc.

Gravity Meter—Gravimeter spring kept at practically constant length by contact stops which close electrical circuits to indicate position of mass. Mass is centered by an auxiliary spring whose position is a measure of gravity.

U.S. #2,159,082, KENNETH HARTLEY, Iss. 5/23/39, Apl. 3/31/34 Assign. Humble Oil and Ref. Co.

Apparatus for Making Gravity Measurements—Various features of gravimeter with main spring and calibrated auxiliary spring. Arrangement of supports, clamping mechanism, spring adjustments, sealed shafts, etc.

MAGNETIC PROSPECTING

U.S. #2,147,942, RANDALL WRIGHT, Iss. 2/21/39, Apl. 4/30/37.

Method for Determining Directional Orientation of Materials—Testing cores for direction of magnetization. Core is suspended on a fiber and placed in a magnetic field to assume orientation indicating its direction of magnetization.

U.S. #2,149,717, J. M. PEARSON, Iss. 3/7/39, Apl. 3/15/38 Assign. Sperry-Sun Well Surveying Co.

Method and Apparatus for Calibrating Magnetometers—Dummy cores or standard loop used to calibrate magnetometers for determining magnetic properties of cores from bore holes.

U.S. #2,151,627, V. V. VACQUIER, Iss. 3/21/39, Apl. 10/28/38 Assign. Gulf Research & Dev'l. Co.

Apparatus for and Method of Measuring the Terrestial Magnetic Field—Absolute vertical intensity magnetometer using Schmidt balance with reversible magnet and Helmholtz coils to neutralize the earth's field, and measurement of the applied field.

SEISMOGRAPH PROSPECTING

U.S. #2,149,427, L. Y. FAUST, Iss. 3/7/39, Apl. 10/12/37 Assign. Geophysical Research Corp'n.

Subsurface Exploration—Seismometer support passes through a tube to make contact only with consolidated stratum to avoid surface waves. Resilient supports may be used to center the support in the tube. Tube may also be used in water.

U.S. #2,151,878, B. B. WEATHERBY, Iss. 3/28/39, Apl. 4/15/37 Assign. Geophysical Research Corp'n.

Seismic Surveying—Shot-hole loaded with long continuous charge or divided charge extending through various formations. This is believed to improve character of arrivals so that correlation is more reliable.

U.S. #2,153,920, L. W. GARDNER, Iss. 4/11/39, Apl. 10/17/36 Assign. Gulf Research & Dev'l. Co.

Seismograph Prospecting—Refraction shooting in which same point of first refraction is used for several shots so that differences of intercept times can be used to determine differences of depth to marker bed at points of second refraction. Shooting around triangles or according to other geometrical patterns using this method.

U.S. #2,154,548, B. B. WEATHERBY, Iss. 4/18/39, Apl. 9/24/36 Assign. Geophysical Research Corp'n.

Seismic Surveying—Reflection shooting. Correlation improved by making a series of records with shots located at different depths to vary the character of the reflections.

U.S. #2,156,198, S. A. SCHERBATSKOY, Iss. 4/25/39, Apl. 2/15/37 Assign. Eng'r Labs. Inc.

Method for Seismic Prospecting—Several closely spaced shots fired in such sequence that the frequency of the wave sent out coincides with the characteristic reflection frequency of some stratum which it is desired to study.

U.S. #2,148,422, L. W. BLAU, Iss. 2/28/39, Apl. 6/26/36 Assign. Standard Oil Dev'l. Co.

Method of Determining the Dips of Geological Strata with Substantially Vertical Reflections—Dip shooting arrangements. Covers locating detectors symmetrically about shot point on one or more straight lines through the shot point. Detectors equally spaced so reflections fall on straight line if weathered layer is uniform. One detector placed above shot point in some cases.

U.S. #2,156,624, L. Y. FAUST, Iss. 5/2/39, Apl. 1/18/38 Assign. Geophysical Research Corp'n.

Subsurface Seismic Surveying—Shots in various holes are placed at such depths that the vertical travel times from shot to surface are equal. This gives more uniform records easier to correlate. Travel time curves are run for each shot hole. Optimum depth for good reflections is determined for one hole and depths for the same travel time are determined from the curves.

U.S. #2,144,812, FRANK RIEBER, Iss. 1/24/39, Apl. 10/3/34 Assign. 1/2 Continental Oil Co.

Method of Geophysical Exploration—Sonograph Analyzer. Various detector outputs are phonographically recorded together, then combined and re-recorded with various

phase displacements between traces so that reflections can be picked out and their direction of arrival determined.

U.S. #2,147,060, F. F. REYNOLDS, Iss. 2/14/39, Apl. 7/23/34 Assign. Seismic Explorations Inc.

Electromagnetic Wave-Pickup Instrument—Suspended magnet detector. Magnet mounted on special flat slotted springs. Magnetic system with adjustable air gaps. Air gap and spring arrangement give critical damping.

U.S. #2,149,442, F. M. KANNENSTINE, Iss. 3/7/39, Apl. 6/11/37

Galvanometer—Galvanometer design. D'Arsonval element fits in a well in permanent magnet. Mirror outside of air gap and perpendicular to coil so that light paths are parallel to flux paths. This makes a flat galvanometer which can be placed close to others without loss of sensitivity.

U.S. #2,155,507, FRANK RIEBER, Iss. 4/25/39, Apl. 1/31/38 Assign. 1/2 Continental Oil Co.

Wave Record Analyzer—Sonograph analyzer. Mechanisms for re-recording several sound track records into a single combined recording. Phase shifter allows proportional adjustment of phase between adjacent traces. Phase may be shifted automatically and progressively after each re-recording of the records.

U.S. #2,158,198, H. R. PRESCOTT, Iss. 5/16/39, Apl. 7/25/35 Assign. Continental Oil Co.

Method and Apparatus for Making Geological Explorations—Seismic amplifier with automatic volume control. Upper and lower limits are set on the control so that the amplifier will not be blocked by excessive signals, and weak signals will be amplified with full gain. Control tube biased either positively or negatively to reduce gain.

U.S. #2,160,224, J. P. MINTON, Iss. 5/30/39, Apl. 11/17/37 Assign. Socony-Vacuum Oil Co., Inc.

Means for Seismic Survey—Derivative-taking circuits to improve sharpness of shot time break.

U.S. #2,161,764, J. P. MINTON, Iss. 6/6/39, Apl. 11/17/37 Assign. Socony-Vacuum Oil Co., Inc.

Method and Means for Recording Seismic Waves—Recording derivatives of seismic waves to improve reflections. Derivator stages are resistance-capacity coupled tube circuits which attenuate all but the highest frequency components.

U.S. #2,164,196, K. C. WOODYARD, C. A. PUTNAM and H. R. PRESCOTT, Iss. 6/27/39, Apl. 3/31/34, Assign. Continental Oil Co.

Means and Method of Making Geophysical Explorations—Impedance of conductors from seismophone are balanced to ground with adjustable voltage divider so that pickup is minimized.

U.S. #2,167,124, J. P. MINTON, Iss. 7/25/39, Apl. 11/17/37 Assign. Socony-Vacuum Oil Co., Inc.

Apparatus for Recording Seismic Waves—Seismic detector mixing circuit which simultaneously allows individual and combined recordings from detectors.

U.S. #2,148,679, L. W. BLAU, R. R. THOMPSON and W. D. MOUNCE, Iss. 2/28/39, Apl. 12/28/34 Assign. Standard Oil Dev'l. Co.

Use of High Frequencies in Measuring Changes in Electrical Impedance—Use of the seismic-electric effect in which variation of earth impedance modulates a high frequency carrier.

U.S. #2,156,259, L. W. BLAU, Iss. 5/2/39, Apl. 12/22/34

Seismic-Electric Prospecting by Means of Continued Waves—Seismic-electric prospecting with continuous waves. Phase of waves may be studied. Surface waves cancelled by spacing electrodes an integral number of wave lengths apart.

GEOCHEMICAL PROSPECTING

U.S. #2,158,980, NILS BRUNDIN, Iss. 5/16/39, Apl. 8/23/37

Method of Locating Metals and Minerals in the Ground—Prospecting by spectroscopically studying chemical content of plants of the same species or humus collected at intervals over an area.

U.S. #2,165,440, G. S. BAYS, Iss. 7/11/39, Apl. 7/22/38 Assign. Stanolind Oil and Gas Co.

Gas Mapping—Values determined for concentration of soil gas are corrected for sorptive power of the soil.

U.S. #2,170,435, W. J. SWEENEY, Iss. 8/22/39, Apl. 12/14/37 Assign. Standard Oil Dev'l. Co.

Gas Analysis Apparatus—Ethane in gas sample detected by burning sample and measuring absorption of infra-red rays passing through the combustion products. For prospecting.

U.S. #2,165,214, L. W. BLAU, and W. B. LEWIS, Iss. 7/11/39, Apl. 6/26/36 Assign. Standard Oil Dev'l. Co.

Geophysical Prospecting with Short Electromagnetic Waves—Analysis of absorption bands in radio short waves or light waves reveals presence of hydrocarbon gases seeping out of soil. Waves may be passed through the air, through a sample container, or may be reflected from the surface of the earth.

WELL LOGGING

U.S. #2,142,555, M. C. BOWSKY, and A. B. WINTER, Iss. 1/3/39, Apl. 1/13/36 Assign. Lane-Wells Co.

Automatic Compensator for Geophysical Devices—Record-tracing device for plotting a varying voltage. Shown for plotting voltage and phase in A.C. well-logging. Vacuum tubes, etc., keep the voltage neutralized and move stilii simultaneously to record the balance point.

U.S. #2,156,052, C. W. COOPER, Iss. 4/25/39, Apl. 4/19/37 Assgin. Halliburton Oil Well Cementing Co.

Logging Device—Acoustic well logging by reflection of sound from bore walls. Directional sound source and receiver in one unit, each inclined to emphasize reflected waves. Nature of formation a predetermined distance from the well is obtained by suitable arrangement of elements.

U.S. #2,156,519, C. P. WALKER, Iss. 5/2/39, Apl. 9/7/37

Means for Measuring the Location of Obstructions in Wells—Pressure pulse well-depth indicator. Frequency of tubing collar reflections emphasized by resonant pipe coupling receiver to well. Velocity of sound is measured by resonance method using a test pipe on the surface filled with well gas. By-pass around receiver dipahragm to adjust sensitivity.

U.S. #2,159,418, EARL BABCOCK, Iss. 5/23/39, Apl. 10/19/36. Assign. Halliburton Oil Well Cementing Co.

Electrical Logging Apparatus—Electrical well logging device comprising a casing with electrodes and recorder lowered into a well as a unit. This eliminates electrical cables to surface.

U.S. #2,165,213, L. W. BLAU and LOUIS STATHAM, Iss. 7/11/39, Apl. 4/8/36. Assign. Standard Oil Dev'l. Co.

Electrical Transient Well-Logging—Transient observed with cathode-ray tube and galvanometer in circuit with well electrode and remote surface electrode. Galvanometer is shunted by inductance to emphasize transients, and may be either high frequency or ballistic type.

U.S. #2,167,066, D. W. ELLIOTT, Iss. 7/25/39, Apl. 3/20/35. Assign. Lane-Wells Co.

Locating Water Strata in Oil Wells—Well electrodes with adjacent saw-tooth edges so that fluctuations in current occur in passing between zones having different conductivity. Water or electrolyte droplets may make direct contact between electrodes.

U.S. #2,167,630, C. B. BAZZONI and JOS. RAZEK, Iss. 8/1/39, Apl. 4/2/36. Assign. Sperry-Sun Well Surveying Co.

Electrical Prospecting Method and Apparatus—Electrical well logging using reaction on oscillator circuit. Varying brilliance of a lamp in oscillator circuit may be recorded photographically. Oscillator may be crystal controlled. An operating condition of oscillator may be kept constant by making adjustments and the amount of adjustment may be used as indication of stratum reaction. Has novel recording mechanism.

U.S. #2,150,169, J. J. JAKOSKY, Iss. 3/14/39, Apl. 3/9/37
Reissue #21,102, Iss. 5/30/39, Apl. 4/5/39

Method and Apparatus for Continuous Exploration of Bore Holes—Drill used as logging electrode by placing earth electrode at a distance from well so that effect of changing resistance at the drill is appreciable, although entire length of drill stem is in contact with formations.

U.S. #2,153,802, J. J. JAKOSKY, Iss. 4/11/39, Apl. 11/23/36

Method and Apparatus for Continuous Exploration of Bore Holes—Electrical well-logging using drill bit as one electrode and placing the other electrode at a distance from the well. Low conductivity fluid in the well. Protectors to help insulate drill stem from bore walls. Uses A.C. or D.C. and makes potential or impedance measurements. Separate surface electrodes may be used for potential measurement.

U.S. #2,155,133, J. J. JAKOSKY, Iss. 4/18/39, Apl. 10/28/36. Assign. Schlumberger Well Surveying Corp.

Electrical Method and Apparatus for Determining the Characteristics of Geologic Formations—Electrical well-logging with two electrodes, one at a distance from the well

and one in the well, so that current flows mostly parallel to the strata. Uses A.C. or D.C. and current, resistance or bridge measurements. Compensating inductance changes as cable is unwound from reel.

U.S. #2,165,013, CONRAD SCHLUMBERGER, Iss. 7/4/39, Apl. 9/10/34. Assign. Schlumberger Well Surveying Corp.

Method and Apparatus for Identifying the Nature of the Formations in a Bore Hole—Electrical well-analysis by measuring polarization effects of direct current. Current is cut off and on and potential is measured during off periods.

THE SOCIETY ROUND TABLE

AMENDMENT TO THE BY-LAWS

The following addition to Article II-A-2 of the By-Laws was authorized by Executive Order Number C-6, dated May 21, 1939, bearing the signatures of the Executive and Business Committees:

"$3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, GEOPHYSICS."

CANCELLATION OF 1939 FALL MEETING

At the annual meeting held at Oklahoma City in March, President Kannenstine appointed E. E. Rosaire chairman of a committee to arrange for a fall meeting of your Society to be held in Houston at a time which would coincide with a scheduled visit to Houston by members of the International Geophysical Union who might elect to make this trip. When your executive committee met in Houston on May 27 last, further preparations were made for this meeting. It was decided to have a symposium of invited papers on the various methods used in geophysical prospecting. Each paper was to require about one hour for its presentation. In addition there was to be a program of contributed papers. Notice to this effect appeared in the July issue of GEOPHYSICS.

Subsequent correspondence between Professor W. T. Thom, Jr. representing the I.G.U. and Chairman Rosaire developed that the visit to Houston would precede the I.G.U. convention and that our meeting dates would have to be August 31 and/or September 1 and that the number of visiting delegates who had signed up for the trip was disappointingly small. In view of these facts your President addressed a letter to the members of the executive committee suggesting that in view of the short time available to the I.G.U. delegates in Houston, the obvious difficulty in having the symposium papers available for so early a date, and the unseasonableness of the date for an S.E.G. meeting, we should drop the plan to have a scheduled meeting and to present the symposium at that time. Also that we have instead a dinner in honor of the visiting delegates with them as our guests and follow the dinner with an informal round table discussion. This plan met the unanimous approval of the executive committee and was therefore adopted.

In the same letter the committee was asked to vote whether it favored holding a fall meeting, at a later date, for the presentation of contributed papers and the symposium. The vote of the committee was against the holding of such a meeting.

The projected symposium will therefore be presented at the annual meeting next spring. The annual meeting of the A.A.P.G. will be held in Chicago on April 10, 11 and 12, 1940. Your executive committee has decided that Chicago is not a suitable place to hold the annual meeting of S.E.G. and will arrange our annual meeting at some other time and place which is as yet unnamed. The meeting is to be at a place more centrally located with respect to the S.E.G. membership in the southwest. The time will probably be some time in March so that both meetings can be attended by those desiring it.

The advent of the war in Europe upset many well laid plans in connection with the I.G.U. assembly in Washington and the only delegate to appear in Houston on August 31 was S.E.G. member Dr. C. A. Heiland. He was met by Messrs. E. E. Rosaire, Blau, Crowell and Horvitz.

The arrangements for the 1940 annual meeting of S.E.G. are in the hands of Messrs. J. H. Crowell and E. E. Rosaire. It is hoped that plans can be fully reported in the January issue of GEOPHYSICS.

ANNUAL MEETING 1940

The following exchange of letters between your President and President Ley of the A.A.P.G. regarding the 1940 annual meetings of the two societies is presented for your information. Reasons for the decision to hold our meeting at a time and place apart from that of the A.A.P.G. are outlined.

August 18, 1939

President Henry A. Ley
American Association of Petroleum Geologists
1042 Milam Building
San Antonio, Texas
Dear President Ley:

At its last meeting the Executive Committee of the Society of Exploration Geophysicists was advised that your Association had narrowed down its choice of place for the 1940 annual meeting to St. Louis and Chicago. The oil developments of the past few years in Illinois no doubt had an important bearing on this choice and there is little doubt that the A.A.P.G. could hold a meeting at either place with every assurance that it would be a successful one. Unfortunately, we seem to have good reason to feel that this is not true of the S.E.G. By far the greater portion of our membership is engaged in field activity and to assure well attended meetings, we cannot go very far outside the area where geophysical field work is largely concentrated. For this reason we regretfully decided that if the A.A.P.G met in St. Louis, we would also meet there and that our respective meetings would be coordinated in the usual manner, but that if the A.A.P.G. met in Chicago, we would hold our meeting separately at some place more centrally located for the geophysicists and at a time that would permit attendance at both meetings.

In reaching this decision the idea was frequently expressed that in the future every reasonable effort should be made to hold S.E.G. annual meetings at the same time and place as those of the A.A.P.G. and it is my hope, which is shared by most, if not all, of my colleagues, that a substantial majority of our future annual meetings will be joint ones.

The decision to hold our 1940 annual meeting at a time and place different from that chosen by the A.A.P.G. for its annual meetings must not be regarded as evidence of conflicting interests, except only that we doubt very seriously whether S.E.G. can hold a meeting well attended by its members in Chicago. For that reason and for it only we will hold our annual meeting probably in one of the oil centers of the southwest. When definite plans have been made, we expect to extend a personal invitation to you to attend our meetings and the Society will welcome the attendance of any members of the A.A.P.G. who may be interested.

Yours very truly,
E. A. Eckhardt, President
Society of Exploration Geophysicists

September 6, 1939

President E. A. Eckhardt
Society of Exploration Geophysicists
P.O. Box 2038
Pittsburgh, Pennsylvania
Dear President Eckhardt:

The American Association of Petroleum Geologists regrets the decision of the Executive Committee of the Society of Exploration Geophysicists not to meet with us in 1940 in Chicago.

This Association and the Society, of which you are president, are important factors in petroleum exploration. Both, in my opinion, will be called upon by our national economy to accelerate their activities as time goes on. Both groups, in my opinion, are destined to be long enduring, and of increasing importance in petroleum exploration. It is, therefore, a pleasure to note the cordiality of your letter, and the expressed hope "that in the future every reasonable effort should be made to hold S.E.G. annual meetings at the same time and place as those of the A.A.P.G. . . . ."

Whatever place you select the A.A.P.G. extends most sincere wishes for a successful and well attended S.E.G., annual meeting. We hope that many of your members will attend our Chicago meeting where they will be cordially welcomed.

Sincerely,
Henry A. Ley, President,
American Association of
Petroleum Geologists.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the Secretary within thirty days. (Names of sponsors are placed beneath the name of each nominee.)

ACTIVE

Walter Douglas Baird
Jack R. Cooper, Thomas J. Etherington, W. R. Ransone

Ygnacio Bonillas
Jack R. Cooper, Thomas J. Etherington (Article III-C-1 of the Constitution)

Charles Barrington Brown
E. E. Rosaire, Paul Weaver (Article III-C-1 of the Constitution)

Carl Lyle Bryan
E. A. Eckhardt, Paul Weaver, R. D. Wyckoff

Teunis de Pijper
J. P. Woods (Article III-C-1 of the Constitution)

Daniel George Emrick
E. A. Eckhardt, Leo J. Peters, Clyde G. Strachan

John Gilbert Ferguson
W. H. Gayman, E. V. McCollum, L. M. Mott-Smith

Daniel Lauder Gerlough
Craig Ferris, L. M. Mott-Smith, C. R. Wallace
Roger Henquet
J. J. Jakosky, E. G. Leonardon, C. H. Wilson
Edgar Rice Locke
George D. Mitchell, Jr., L. A. Scholl, Jr., C. C. Zimmerman
Emanuel Maxwell
Alfred J. Herzenberg, David S. Muzzey, Jr., J. P. Woods
Waynard Burton Perry
T. A. Manhart, Keith H. Odenweller, G. H. Westby
Raymond Alfred Peterson
Herbert Hoover, Jr., H. Hart Pratley, Harold Washburn
Nat Harman Prade
L. M. Mott-Smith, G. H. Samuels, Jr., J. H. Sawyer
George Arnold Schofield
George D. Mitchell, Jr., L. A. Scholl, Jr., C. R. Wallace
Frank Siegel
D. F. Broussard, T. I. Harkins, A. L. Smith
Paul Edwin Swenson
Jack R. Cooper, Thomas J. Etherington, W. R. Ransone
William John Thomas
G. W. T. Barnett, R. Davies, D. T. Germain-Jones

ASSOCIATE

Warren Amos Alexander
A. B. Bryan, Robert S. Dahlberg, Jr., S. Zimerman
Francis Harold Cady
A. B. Bryan, George E. Wagoner, S. Zimerman
James Stinson Hopkins
L. Y. Faust, K. M. Lawrence, O. C. Lester, Jr.
Milton Edwin Loy
Norman J. Christie, H. Hart Pratley, Sibyl M. Rock
Georg Heinrich Markstein
George H. Samuels (Article III-C-1 of the Constitution)

PERSONAL ITEMS

Mr. R. D. Wyckoff of the Gulf Research and Development Company has transferred his offices from Houston to Pittsburgh, Pennsylvania.

The January issue of GEOPHYSICS for 1940 will contain a complete listing of society publications, with the articles individually listed.

Gifford E. White may now be reached at the Graduate House of the Massachusetts Institute of Technology in Cambridge.

Jake Moon has returned from Colombia to work in the States for Geophysical Service, Incorporated, of Dallas, Texas.

James A. Moore of the Petty Geophysical Engineering Company has been transferred from Victoria, Texas, and may be addressed at Box 836, Lake Charles, Louisiana.

John H. Hodgson has left the employ of the Magnolia Petroleum Company to return to the University of Toronto in Canada.

G. F. Kaufmann has been transferred from Caripito, Venezuela, and may be addressed c/o Standard Oil Company of Venezuela, Apartado 1329, Caracas, Venezuela.

V. G. Gabriel has moved to Pasadena, California, to do consulting work. He may be addressed at 290 South Michigan Avenue in that city.

Charles C. Mason has returned from Venezuela to his position with the Humble Oil and Refining Company in Houston, Texas.

Sibyl M. Rock has entered the employ of the United Geophysical Company in Pasadena, California.

Floyd Perkinson vacationed in Purcell, Oklahoma, prior to returning to work for Compania Consolidado de Petroleo, Apartado 1706, Caracas, Venezuela.

P. M. Honnell has received an appointment to the California Institute of Technology. His Pasadena address is 615 South El Molino Avenue, Apartment #4.

Andrew H. Gay of the Grantland Production Corporation has advised that offices have been moved from 613 Pere Marquette Building to 637 Canal Bank Building, New Orleans, Louisiana.

Sam Zimerman of the Carter Oil Company has been transferred from Maryville, Missouri, to Aberdeen, Mississippi, where he may be addressed at Box 252.

B. D. Lee has left Los Angeles, California, to work in South America. His mailing address is c/o T. F. Roche, Apartado Postal #159, Barranquilla, Colombia.

L. F. Fischer has been transferred from Magnolia, Arkansas to Tyler, Texas, where he may be reached at Box 733.

J. G. Kearby is now Technical Editor of the publication, *Drilling*, with offices on the fourth floor of the Melba Building, Dallas, Texas.

H. W. Straley, III has moved to Waco, Texas, to accept an appointment at Baylor University. He may be addressed at Box 363.

George H. Rabson has left the employ of Subterrex. His address is 1950 Lexington, Houston, Texas.

L. I. Freeman is handling the affairs of the Heiland Research Corporation in Shreveport, Louisiana, with offices at 727 Giddens-Lane Building.

A. van Weelden, after attending the congress of the International Union Geophysical in Washington, D. C., has been traveling in the United States. He will return to Europe in November, but prior to that time, may be reached through the Houston or St. Louis offices of the Shell Oil Company.

George B. Somers has returned from work in Germany to his position with the Magnolia Petroleum Company in Dallas, Texas.

Robert L. Craig has been transferred from Hungary to England. He may be addressed c/o Standard Oil Company of New Jersey, Postbox 392, The Hague, Holland.

Ralph C. Loring is now working for the Humble Oil and Refining Company in Houston, Texas, and may be addressed at 812 Bell Avenue.

John W. Hull has left Subterrex to accept a fellowship at the University of Texas in Austin. He is located at 2000 East Avenue in that city.

C. Bradner Brown, of the McCollum Exploration Company, has been transferred from Houston, Texas, to McAllen, Texas, where he may be addressed at Box 889.

Norman A. Haskell has been transferred from Inglewood, California, and may be reached through the Western Geophysical Company, 601 West 5th Street, Los Angeles, California.

W. B. Agocs has returned from Venezuela and may be addressed at 940 Broadway, Bethlehem, Pennsylvania.

John F. Imle is now with the Petty Geophysical Engineering Company of San Antonio, Texas.

George Davenport has resumed his studies at the University of Texas.

R. Maurice Tripp has returned from the Colorado School of Mines to his position with the Geotechnical Corporation, 1702 Tower Petroleum Building, Dallas, Texas.

Paul B. Brown is now working in South America for the Mott-Smith Corporation. His address in Barranquilla, Colombia, is Apartado Aereo 32, Apartado Nacional 159.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

Constitution and By-Laws
(As amended to May 21, 1939)

I. Name

This Association shall be called the "Society of Exploration Geophysicists."

II. Object

The object of this Association is to promote the science of geophysics especially as it applies to exploration.

III. Membership

A—Members

1. Any geophysicist of recognized standing shall be eligible to membership, whether or not he is engaged in petroleum geophysics or in geophysical prospecting.
2. Any physicist, mathematician, geologist, or engineer of recognized standing who is investigating a geophysical problem or problems shall be eligible to membership.
3. Any geologist of recognized standing who is not a geophysicist of recognized standing, but who is acting as chief, or division chief in charge of geophysical surveying, shall be eligible to membership.

B—Associates

1. Any geophysicist, geologist, engineer, mathematician, or physicist who is a graduate of an institution of recognized scientific standing who is engaged in geophysics and who is not eligible to membership shall be eligible to associate membership.
2. Any person who is not a graduate of an institution of recognized scientific standing and who is not eligible to membership and who has shown ability in a routine phase of geophysical work and who is in a position of responsibility in geophysical surveying shall be eligible to associate membership.
3. Any representative or employee of a firm or corporation engaged in supplying equipment or supplies to the geophysical prospecting industry, provided such individual is the graduate of an institution of recognized scientific standing, or provided otherwise that such individual is qualified by adequate technical experience shall be eligible to associate membership.
4. Associate members shall be known as associates.
5. Associates shall enjoy all the privileges of membership in the Society, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Society in professional cards or professional reports or otherwise.
6. The Executive Committee may advance to active membership, without the formality of application for such change, those associates who have, subsequent to election, fulfilled the requirements for active membership.

C—Election to Membership

1. Every candidate for admission as a member or associate shall submit a formal application on an application form authorized by the Executive Committee, signed by him, and endorsed by not less than three members who are in good

standing, stating his training and experience and such other facts as the Executive Committee shall from time to time prescribe. Provided the Executive Committee, after due consideration, shall judge that the applicant's qualifications meet the requirements of the Constitution, they shall cause to be published in an appropriate publication the applicant's name and the names of his sponsors. If, after at least thirty days have elapsed since such publication, no reason is presented why the applicant should not be admitted, he shall be deemed eligible to membership or to associate membership, as the case may be, and shall be notified of his election. Provided the Executive Committee may accept applicants for either class of membership, who, because of their geographical location or because of their lack of acquaintance with active members of this Society, are unable to secure qualified sponsors, but who otherwise are eligible for membership.

2. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the regular Society publications for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice has been mailed of his election, the Executive Committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the current year and until such written notice and card are received, he shall in no way be considered a member of the Society.

D—Honorary Members

1. The Executive Committee may from time to time and by unanimous action elect as honorary members persons who have contributed distinguished service to the cause of geophysics. Honorary members shall not be required to pay dues.

E—Code of Ethics

1. Membership of any class shall be contingent upon conformance with the established principles of professional ethics.

IV

A—Resignation—Suspension—Expulsion

1. Any member or associate may resign from the Society at any time. Such resignation shall be in writing and shall be accepted by the Executive Committee, subject to the payment of all outstanding dues and obligations of the resigning member or associate.
2. Any member or associate who is more than one year delinquent (in arrears) in payment of dues shall be suspended from the Society. Any delinquent or suspended member or associate, at his own option, may request in writing that he be dropped from the Society and such request shall be granted by the executive committee. Any member or associate more than two years in arrears shall be dropped from the Society. The time of payment of delinquent dues for either one year or two years may be extended by unanimous vote of the Executive Committee.
3. Any member or associate who resigns or who is dropped under the provisions of

Sections 1 and 2 of this article ceases to have any rights in the Society and ceases to incur further indebtedness to the Society.

4. Any person who has ceased to be a member or associate under Section 1 or Section 2 of this article may be re-instated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member or associate of the Society.
5. Any member or associate who, after being granted a hearing by the Executive Committee, shall be found guilty of a violation of the code of ethics of this Society or shall be found guilty of a violation of the established principles of professional ethics or shall be found guilty of having made a false or misleading statement in his application for membership in the Society, shall be asked to resign from the Society by unanimous vote of the Executive Committee. The decision of the Executive Committee in all matters pertaining to the interpretation and execution of the provisions of this section shall be final.

V. Officers and their Duties

A—Officers

1. The officers of the Society shall be a President, a Vice-President, a Secretary-Treasurer, and an Editor. These, together with the Past President, shall constitute the Executive Committee and managers of the Society.
2. A ticket of nomination for officers and representatives shall be prepared by a Committee on Nominations which shall consist of the President and the two qualified Past Presidents in order of precedence. Favorable action of this Committee shall be two out of three votes. The ticket decided on by this Committee, as well as any ticket presented in writing and signed by twenty other members in good standing, shall be submitted to the President by December 31st. At least three candidates for president shall be named on the ticket whenever the incumbent vice-president shall be ineligible for re-election. This shall be placed on a ballot and one mailed to each member in good standing on December 31st by the Secretary-Treasurer, not later than January 10th. A blank space shall be left on this ballot for writing in nominations for each place. Before ballots are mailed the President shall secure written acceptance of nomination from each candidate.

   The nominations for President shall be alphabetically arranged, except the retiring Vice-President, who shall automatically occupy first place on the ticket Each member shall express a first choice for President, and a second choice for another candidate for President. First choice votes shall count double and second choice shall count single. The candidate receiving the highest number of votes so cast and counted shall be elected President, and the candidate receiving the second highest number of votes so cast and so counted shall be elected Vice-President, except where the choice conflicts with Section Three of Article V, in which case the next highest candidate shall be elected Vice-President.

   Each member shall express one choice for Secretary-Treasurer, and one choice for Editor. The candidates securing the highest number of votes so cast and counted shall be elected Secretary-Treasurer and Editor, respectively.

   Such ballots, to be counted as valid, must be received by the Secretary-Treasurer at his officially recognized address not less than ten days prior to the Annual

Meeting. The ballots shall be mailed to the Secretary-Treasurer in envelopes which shall carry the written signature and the typewritten name of the member. These ballots will be opened and counted by the Nominating Committee immediately before the Annual Meeting. The Secretary-Treasurer, before the ballots are opened, shall approve by initialing only those ballots received from members in good standing at the time the ballots are presented to the Nominating Committee for counting.

The announcement of the election will be made as the first of the new business considered at the Annual Meeting. A majority vote of said ballots received in accordance with this action, except where otherwise designated, shall be considered as the will of the Society. In the event of a tie, the favoring secret vote of the Nominating Committee shall decide.

3. No one shall hold the office of President for two consecutive years and no one shall hold any other office for more than two consecutive years except the Editor, who shall not hold office for more than six consecutive years.

B—Duties of Officers

1. The President shall be the presiding officer at all the meetings of the Society, shall take cognizance of the acts of the Society and of its officers, shall appoint such committees as are required for the purposes of the Society, and shall delegate members to represent the Society. He may, at his option, serve on, and may be chairman of, any committee.
2. The Vice-President shall assume the office of President in case of a vacancy from any cause in that office and shall assume the duties of President in case of the absence or disability of the latter. He shall also act as Chairman of the Program and Arrangements Committee of the Society.
3. The Secretary-Treasurer shall assume the duties of the President in case of the absence of both the President and Vice-President. He shall have charge of the financial affairs of the Society and shall annually submit reports as Secretary-Treasurer covering the fiscal year, which he shall arrange to have published in the next regular issue of the recognized organ of the Society. He shall receive all funds of the Society and, under the direction of the Executive Committee, shall disburse all funds of the Society. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded, all employees to whom authority may be delegated to handle Society funds. The amount of such bonds shall be set by the Executive Committee and the expense shall be borne by the Society. The funds of the Society shall be disbursed by check as authorized by the Executive Committee.
4. The Editor shall be in charge of the editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the regular Society publication and for special publications, and may accept or reject material offered for publication. He may appoint associate, regional, and special editors.
5. In the event of absence, disability or resignation of any member of the Executive Committee, the vacant place in the Committee shall be automatically filled by the next preceding qualified Past President who shall be known as Prior Past President.

6. The officers shall assume the duties of their respective offices immediately after the Annual Meeting following their election.

VI. Executive Committee—Meetings and Duties

A—Executive Committee

1. The Executive Committee shall consist of the President, Past President, Vice-President, Secretary-Treasurer, and Editor.

B—Meetings and Duties

1. The Executive Committee shall meet preceding the annual meeting and at the call of the President may hold meetings when and where thought advisable, to conduct the affairs of the Society. A joint meeting of the outgoing and incoming Executive Committees shall be held immediately after the close of the annual Society business meeting. Members of the Executive Committee may vote by proxy, mail or person on all matters which call for favorable or unanimous action.
2. The Executive Committee shall consider all nominations for membership and pass on the qualifications of the applicants, shall have control and management of the affairs and funds of the Society, shall determine the manner of publication, and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Society, and to employ such persons as are needed to conduct the business of the Society. They are empowered to make investments of both general and special funds of the Society. Trust funds may be created giving to the trustees appointed for such purpose such discretion as to investments as seems desirable to the Executive Committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice. Favorable action shall consist of a favoring three out of five votes. Committee members may vote by person, proxy or in writing.

VII

A—Meetings

1. The Society shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held at a time and place designated by the Executive Committee. At this meeting the proceedings of the preceding meeting shall be read, Society business shall be transacted, scientific papers shall be read and discussed, and results announced of the mail ballot for officers for the ensuing year.

VIII

A—Amendments

1. Amendments to this Constitution may be proposed by a resolution of the Executive Committee, by a Constitutional Committee appointed by the President, or in writing by any ten members of the Society. All such resolutions or proposals must be submitted at the annual meeting of the Business Committee of the Society as provided in the By-Laws, and only the Business Committee shall make recommendations concerning proposed constitutional changes at the annual Society business meeting. If such recommendations by the Business Committee shall be favorably acted on at the annual Society business meeting, the Secretary-Treasurer shall arrange for a ballot of the membership by mail within thirty

(30) days after said annual Society business meeting, and a majority vote of the ballots received within ninety (90) days of their mailing shall be sufficient to amend. The legality of all amendments must be determined by the Executive Committee prior to balloting.

B—Parliamentary Regulations

1. The rules contained in "Robert's Rules of Order, Revised" shall govern the Society in all cases to which they are applicable, and in which they are not inconsistent with the By-Laws or the special rules of order of this Society.

BY-LAWS

I

A—Dues

1. The fiscal year of the Society shall correspond with the calendar year.
2. The annual dues of members of the Society shall be five dollars ($5.00). The annual dues of associates for not to exceed six years after election shall be four dollars ($4.00); thereafter, the annual dues of such associates shall be five dollars ($5.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members or associates who shall fail to pay their annual dues by March fifteenth shall not receive further copies of the regular Society publication, shall not be eligible to vote, nor shall they be privileged to buy Society special publications at prices made to the membership, until such arrears are met.

II

A—Publications

1. The proceedings of the annual meeting, the Constitution and By-Laws, and the papers presented at such meeting shall be published at the discretion of the Executive Committee in the regular publication or in such other form as the Executive Committee may decide best meets the needs of the membership of the Society.
2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge the regular publication of the Society for that year. $3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, GEOPHYSICS.
3. The Executive Committee may authorize the printing of special publications to be financed by the Society from its general, publication or special funds and offered for sale to members and associates in good standing at not less than the cost of publication and distribution.

III

A—Regional Sections, Technical Divisions, and Affiliated Societies.

1. Regional sections of the Society may be established provided the members of such sections are members of the Society and shall perfect an organization and make application to the Executive Committee. The Executive Committee shall submit the application for action first by the Business Committee and second to the Society for a letter ballot as for a constitutional amendment, and pro-

vided that the Society may revoke the charter of any regional section by similar action.

2. The Executive Committee may arrange for the affiliation with the Society of duly organized groups or societies, which by object, aims, constitution, by-laws, or practice are developing the study of geophysics or petroleum technology. In like manner, the Executive Committee may arrange conditions for dissolution of such affiliations. Affiliation with the Society need not prevent affiliation with other scientific societies. Members of affiliated societies who are not members of the Society, shall not have the privilege of advertising their affiliation with the Society on professional cards or otherwise, but shall be entitled to receive the regular publication of the Society upon payment of a fee equivalent to that charged an associate member.

IV

A—District Representatives

1. The Executive Committee may cause to be elected district representatives from districts which it shall define by a local geographic grouping of the membership. Such districts shall be redesignated and redefined by the Executive Committee as often as seems advisable. Each district shall be entitled to one representative for each seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the Executive Committee. They shall hold office for two years, their term office expiring at the close of the annual meeting. In so far as possible, these two-year terms shall be overlapping.

V

A—Business Committee

1. The Executive Committee may institute a Business Committee to act as a council and advisory board to the Executive Committee and the Society. This Committee shall consist of the Executive Committee, the Prior Past President, and the district representatives. Favorable action by the Business Committee shall consist of a favorable two-thirds vote. The Secretary-Treasurer shall act as Secretary of the business meeting. Members of this Committee may vote in person, by proxy, or in writing. The Business Committee shall meet the day before the annual meeting at which time proposed changes in the Constitution or By-Laws may be considered, all old and new business shall be discussed, and recommendations may be voted for presentation at the annual meeting.

VI

A—Amendments

1. These by-laws may be amended by favorable vote of the Business Committee, providing that such changes have been recommended and legality approved by the Executive Committee. Such amendments shall be published in the next regular number of the recognized organ of the Society.

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A Journal of General and Applied Geophysics

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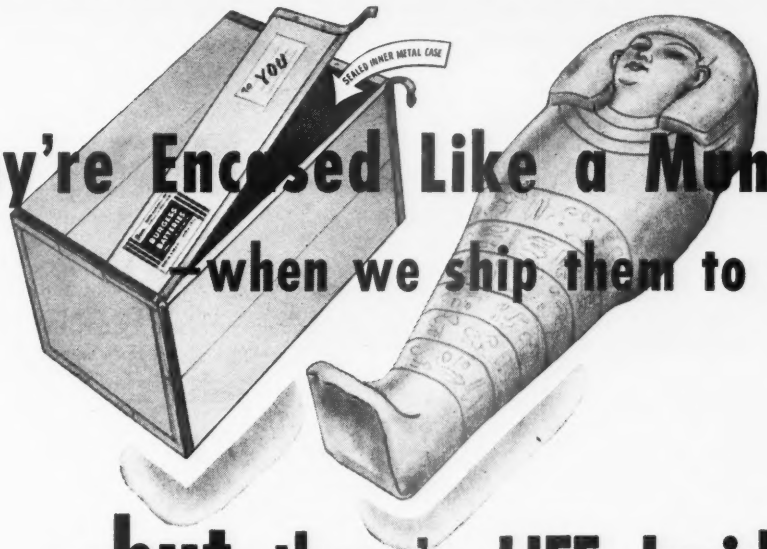

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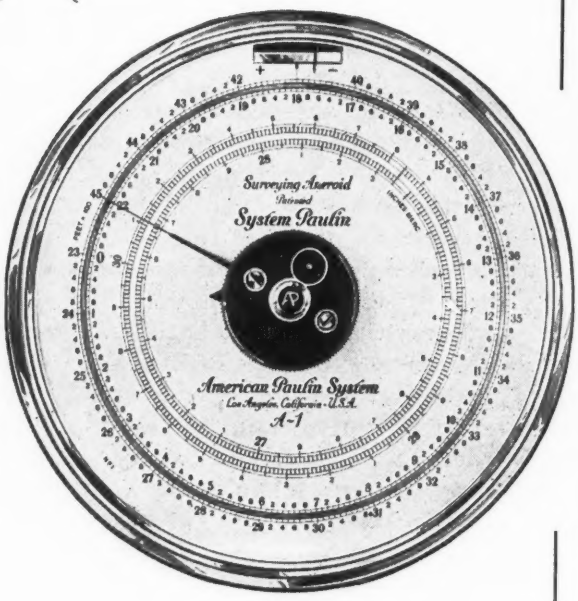

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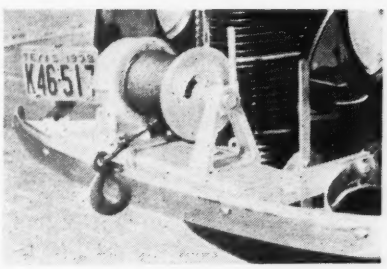

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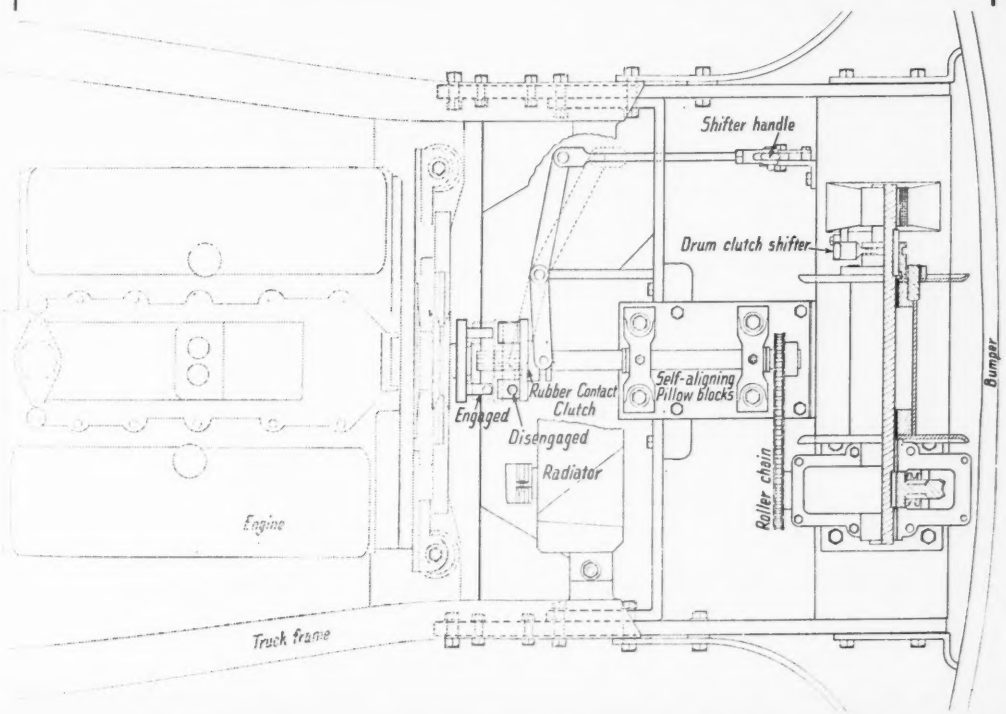

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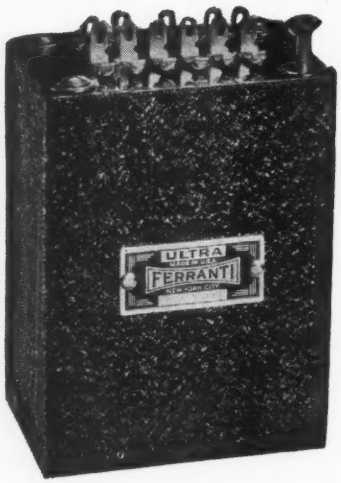

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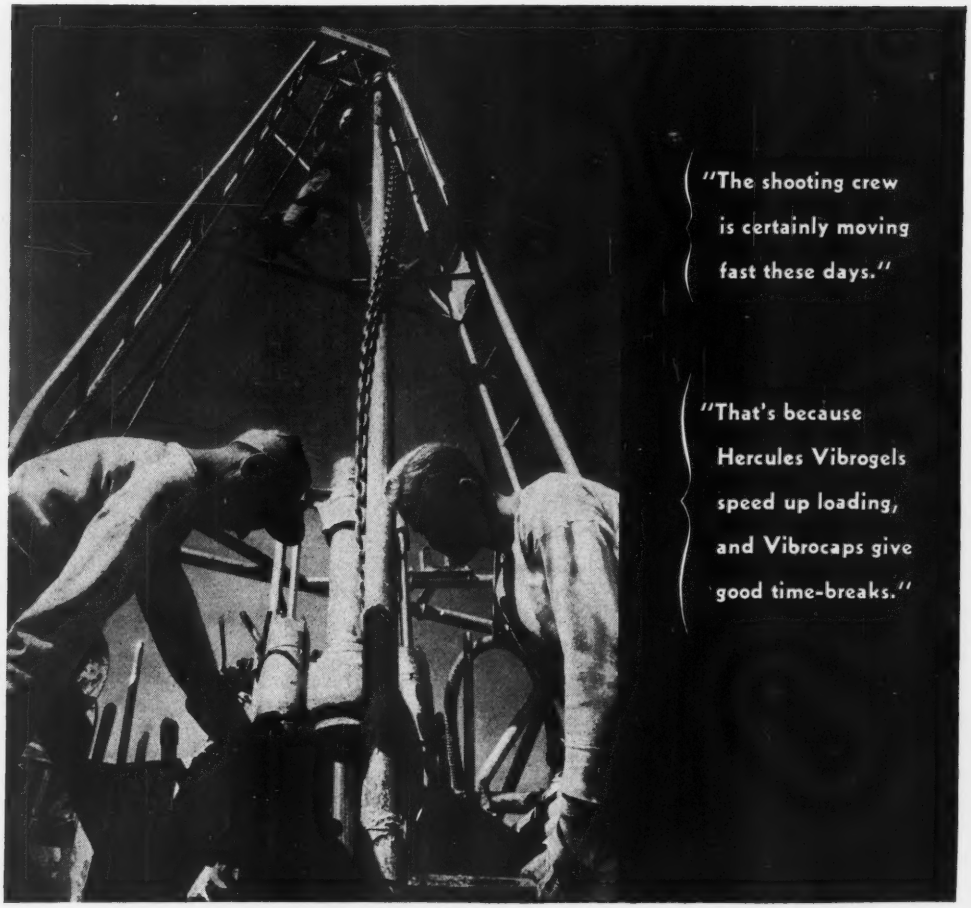
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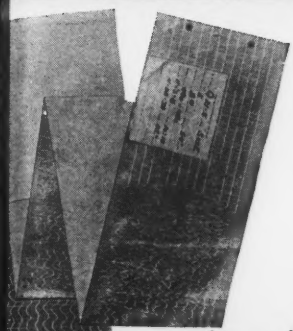

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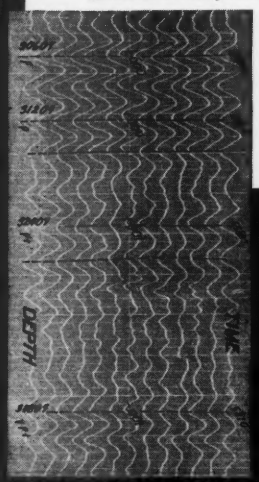

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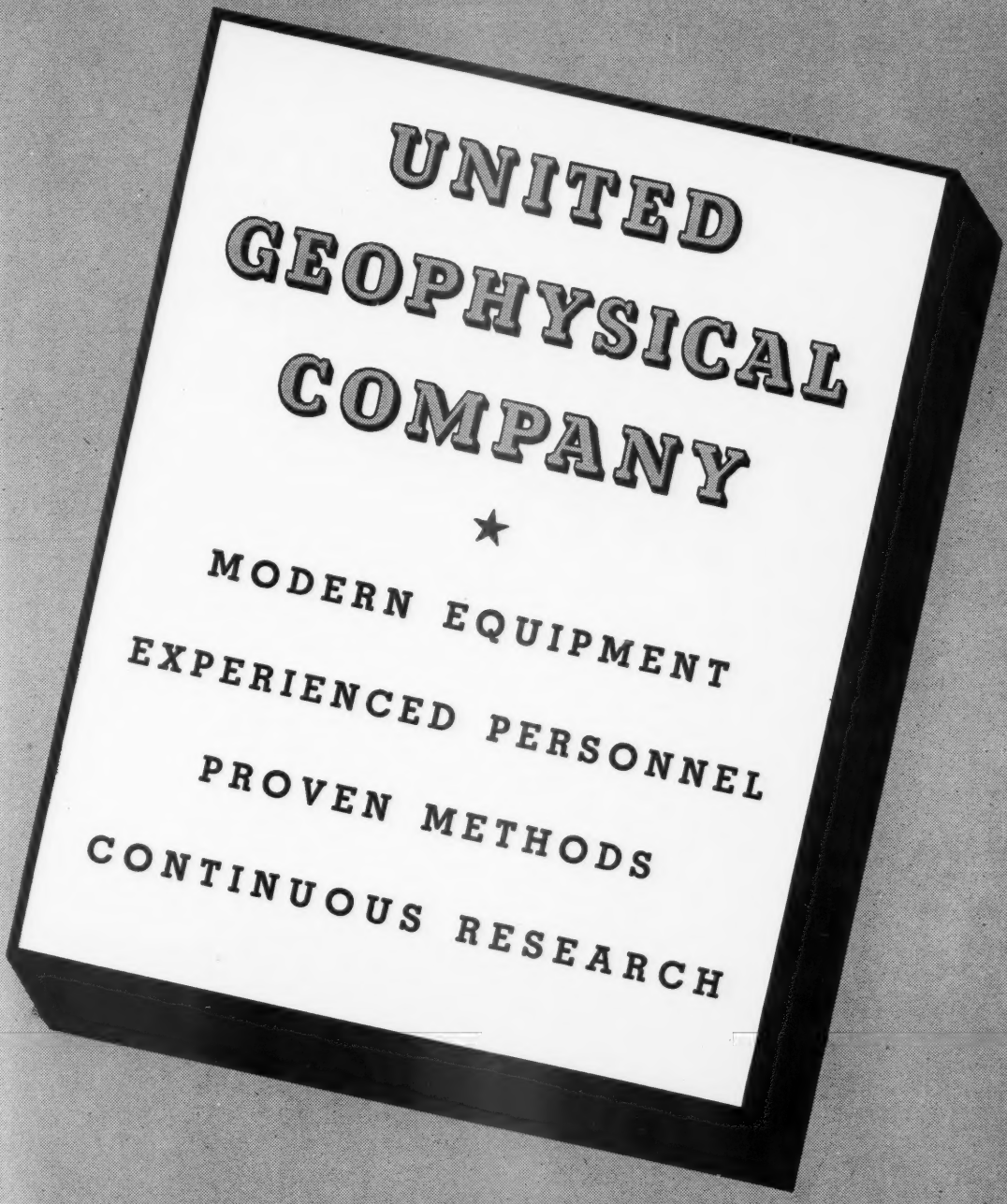

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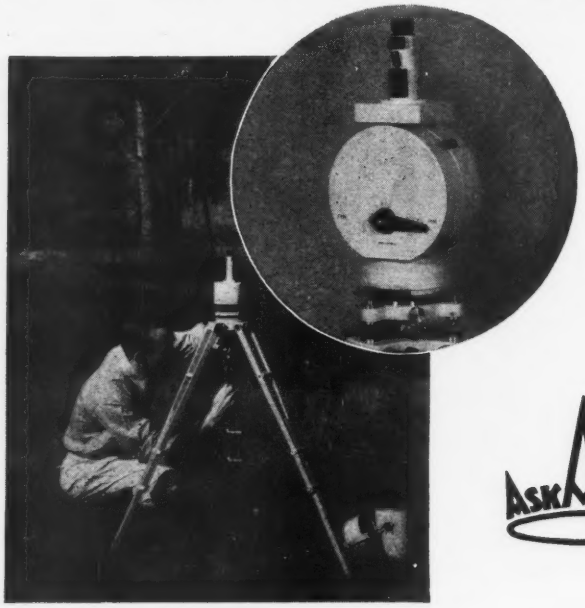

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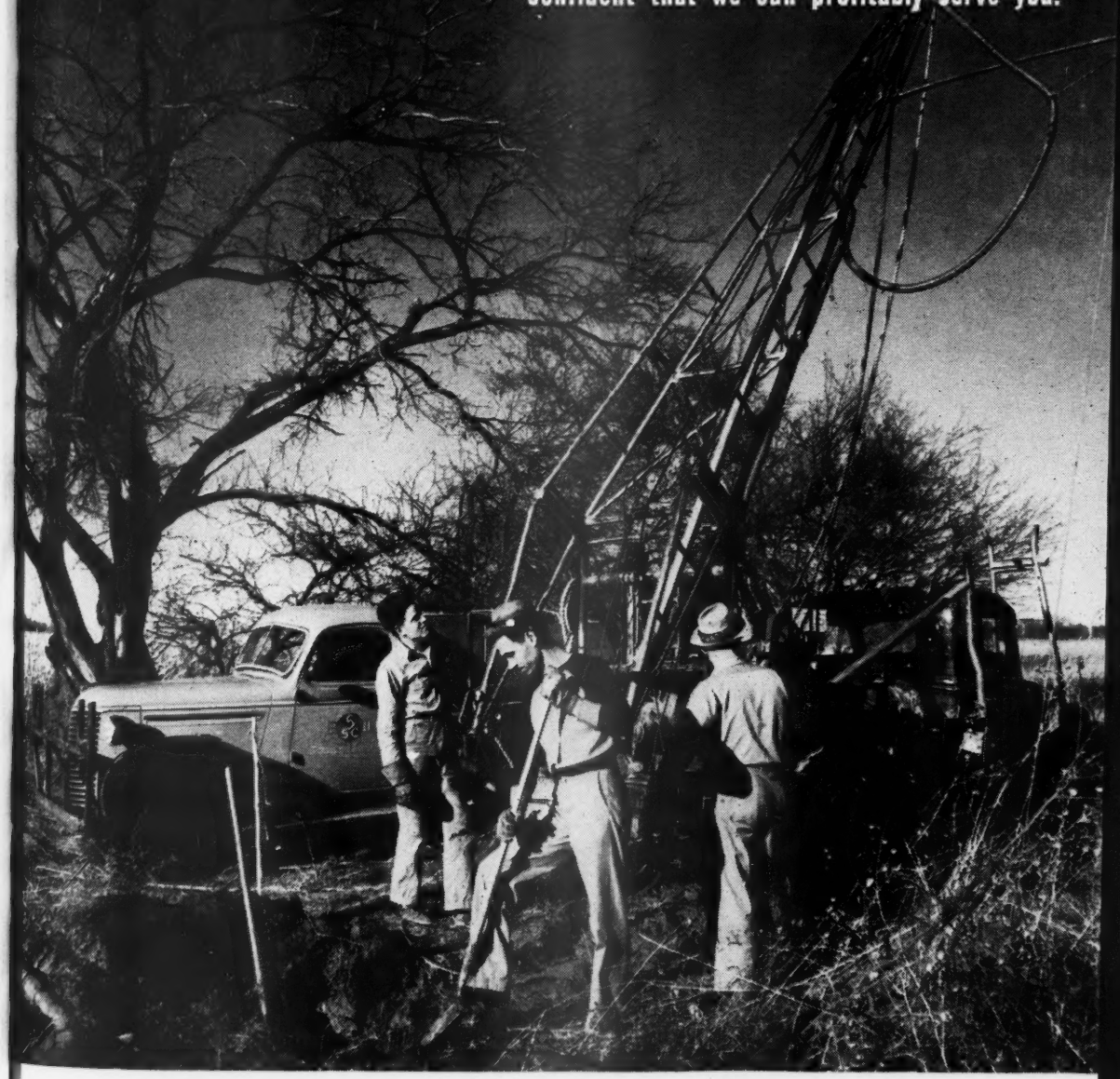

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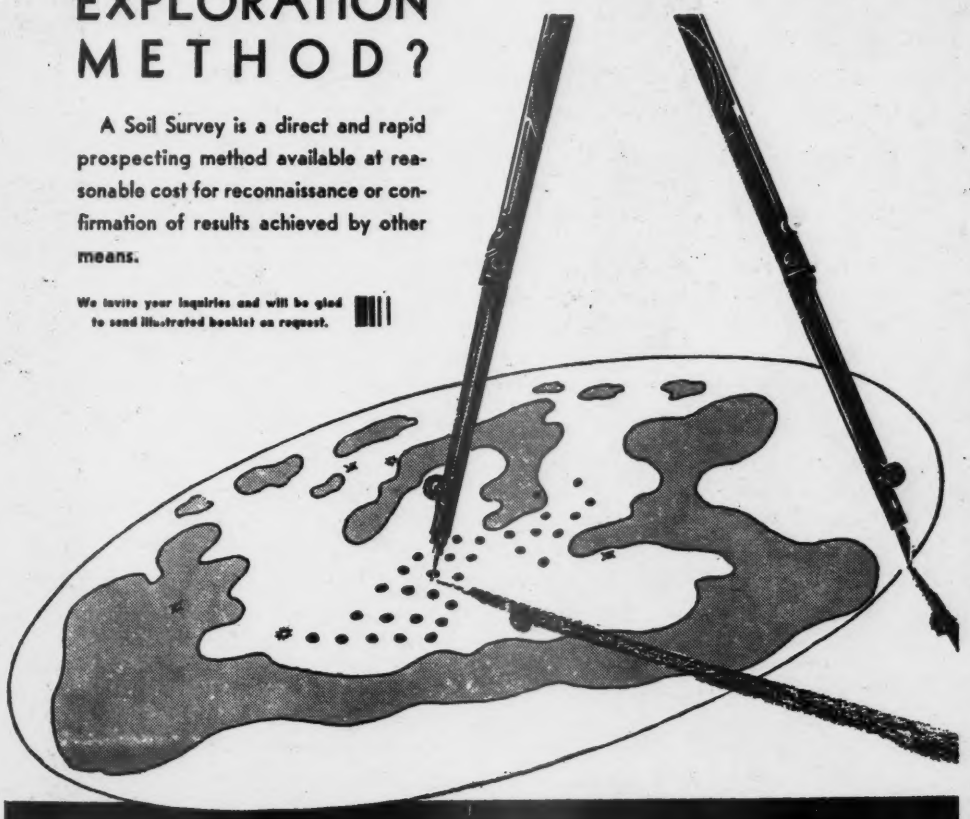

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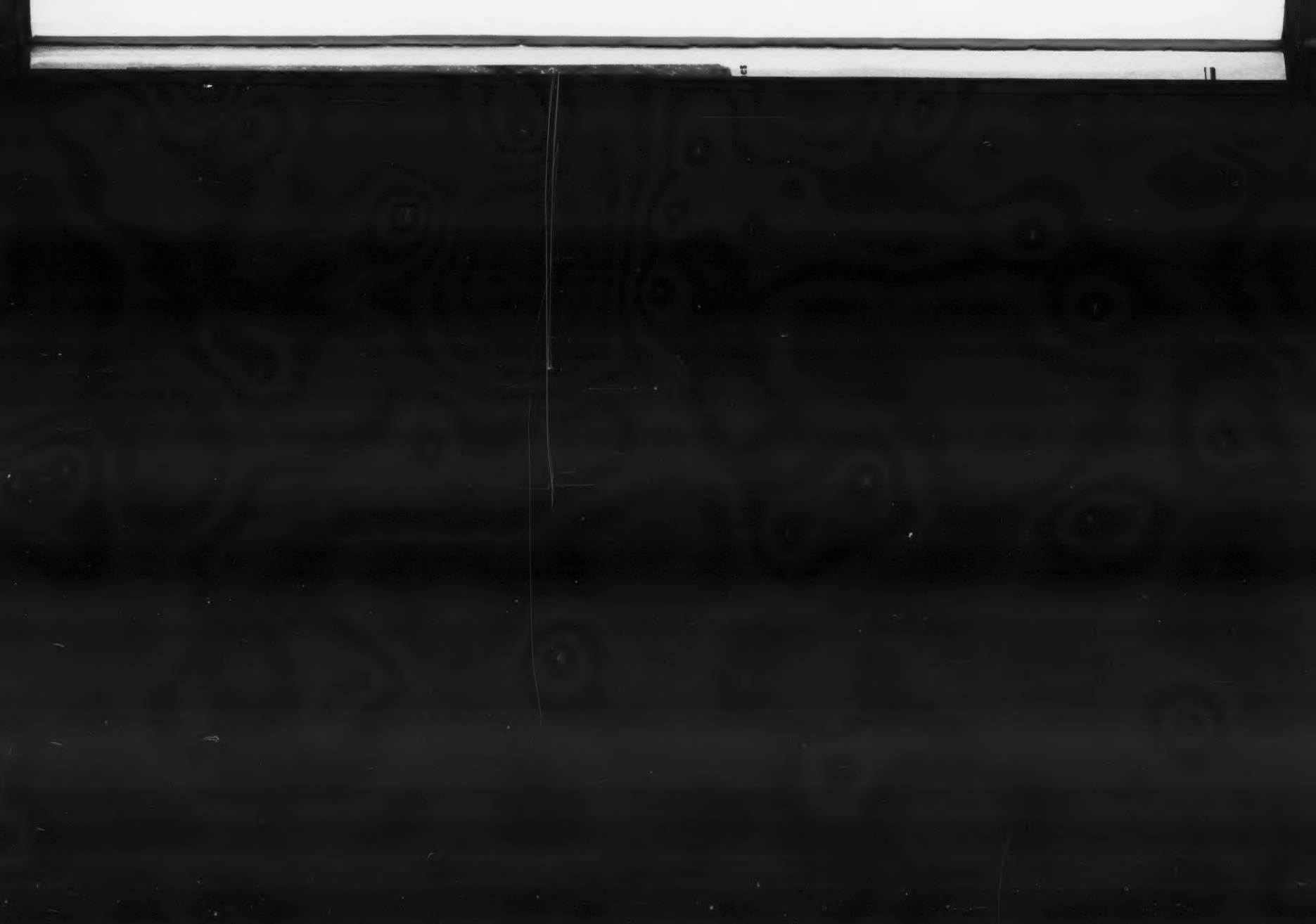
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